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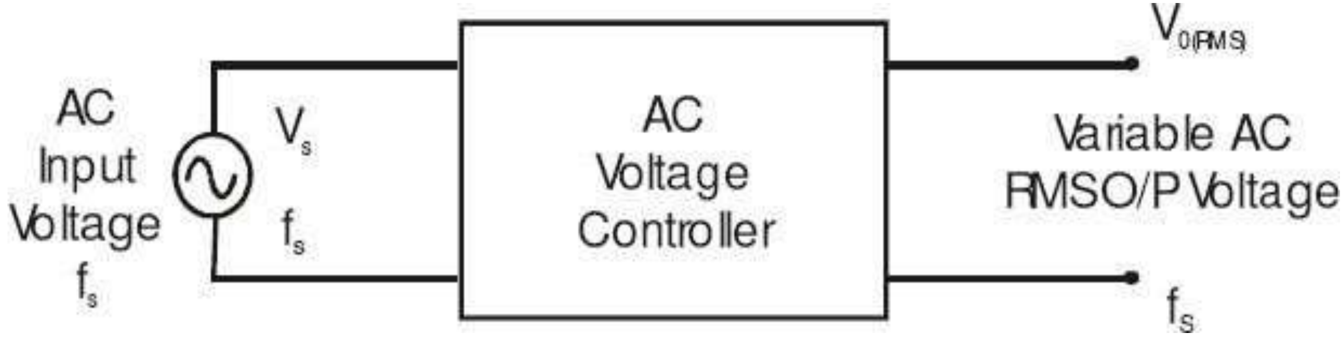
UNIT-V

AC-AC Converters

Prepared by
Ch. Prasanna.
Assistant Professor, EEE

Ac Voltage controller circuits (RMS voltage controllers)

An ac voltage controller is a type of thyristor power converter which is used to convert a fixed voltage, fixed frequency ac input supply to obtain a variable voltage ac output



Applications Of Ac Voltage Controllers

- Lighting / Illumination control in ac power circuits.
- Induction heating.
- Industrial heating & Domestic heating.
- Transformer tap changing (on load transformer tap changing).
- Speed control of induction motors C magnet controls.

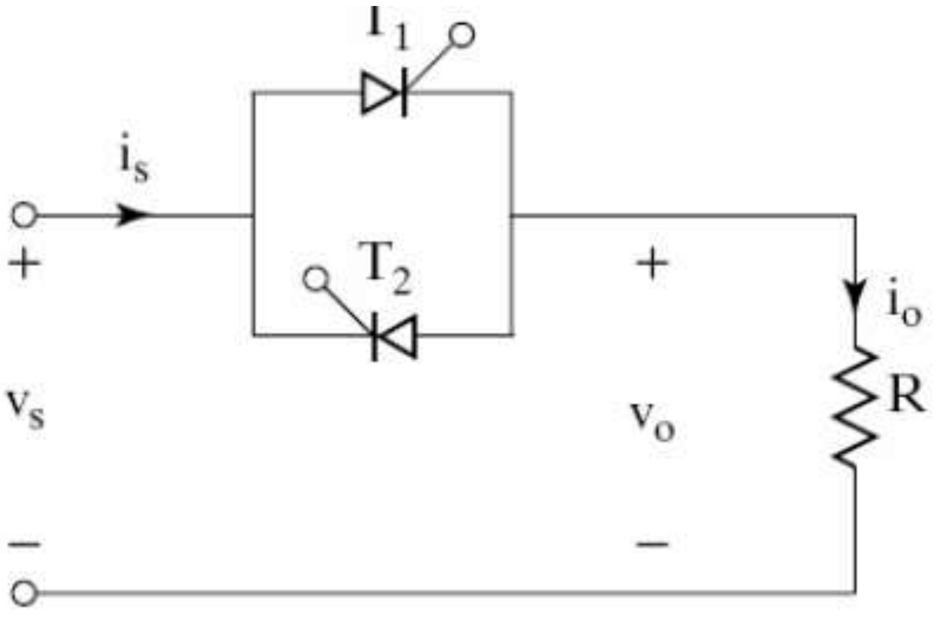
Type Of Ac Voltage Controllers

- Single phase half wave ac voltage controller (Uni-directional controller).
- Single phase full wave ac voltage controller (Bi-directional controller).
- Three phase half wave ac voltage controller (Uni-directional controller).
- Three phase full wave ac voltage controller (Bi-directional Controller)

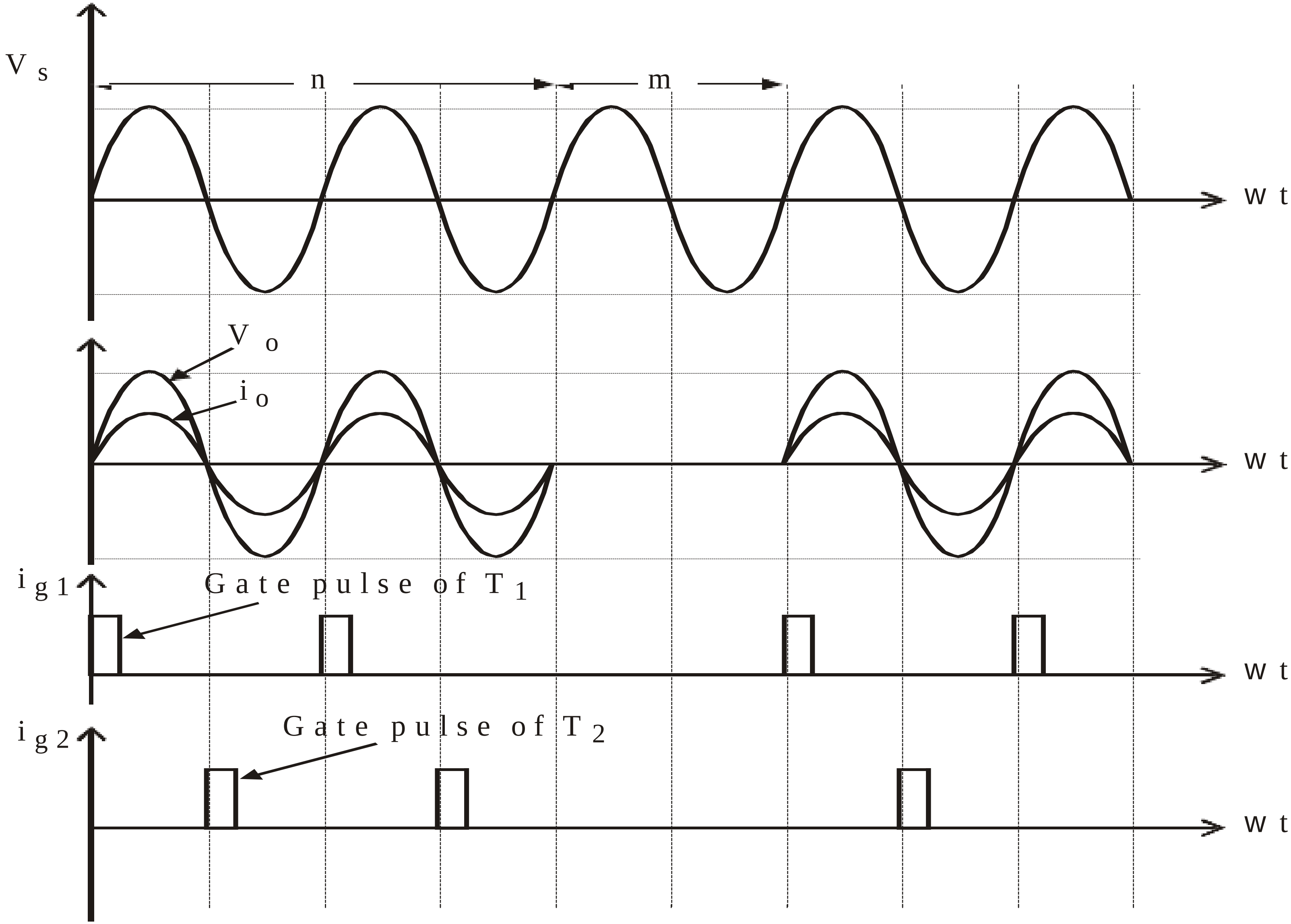
A.C voltage control technique

- On-Off control.
- Phase control.

Principle of ON-OFF Control Technique



Single phase full wave AC voltage controller circuit


V s
n
m
w t
V o
i o
w t
i g 1
Gate pulse of T 1
w t
i g 2
Gate pulse of T 2
w t

For a sine wave i/p ac supply

$$v_s = V_m \sin \omega t = \sqrt{2} V_S \sin \omega t$$

$$V_S = \frac{V_m}{\sqrt{2}} = \text{RMS value of i/p ac supply}$$

$$t_{ON} = n \times T, \qquad t_{OFF} = m \times T$$

n = no. of i/p cycles during on time t_{ON}

m = no. of i/p cycles during off time t_{OFF}

$$T = \frac{1}{f} = \text{input cycle time (time period)}$$

$$f = \text{input supply frequency.}$$

$$t_{ON} = \text{controller on time} = n \times T$$

$$t_{OFF} = \text{controller off time} = m \times T$$

$$T_O = \text{Output time period}$$

$$= \left(t_{ON} + t_{OFF}\right) = \left(nT + mT\right)$$

For on-off control method

$$V_{O(RMS)} = V_{i(RMS)} \sqrt{\frac{t_{ON}}{T_O}} = V_S \sqrt{\frac{t_{ON}}{T_O}}$$

Expression For The RMS Value Of Output Voltage, For ON-OFF Control Method

$$V_{O(RMS)} = \sqrt{\frac{1}{\omega T_O} \int_{\omega t=0}^{\omega t_{ON}} V_m{}^2 Sin^2 \omega t.d\left(\omega t\right)}$$

$$V_{O(RMS)} = \sqrt{\frac{V_m{}^2}{\omega T_O} \int_{0}^{\omega t_{ON}} Sin^2 \omega t.d\left(\omega t\right)}$$

Substituting for $Sin^2\theta = \frac{1 - Cos2\theta}{2}$

$$V_{O(RMS)} = \sqrt{\frac{V_m{}^2}{\omega T_O} \int_{0}^{\omega t_{ON}} \left[\frac{1 - Cos2\omega t}{2}\right] d\left(\omega t\right)}$$

$$V_{O(RMS)} = \sqrt{\frac{V_m^{\ 2}}{2\omega T_O}\left[\int_0^{\omega t_{ON}} d\left(\omega t\right) - \int_0^{\omega t_{ON}} Cos2\omega t.d\left(\omega t\right)\right]}$$

$$V_{O(RMS)} = \sqrt{\frac{V_m^{\ 2}}{2\omega T_O}\left[\left(\omega t\right)\Big/_0^{\omega t_{ON}} - \frac{Sin2\omega t}{2}\Big/_0^{\omega t_{ON}}\right]}$$

$$V_{O(RMS)} = \sqrt{\frac{V_m^{\ 2}}{2\omega T_O}\left[\left(\omega t_{ON} - 0\right) - \frac{\sin 2\omega t_{ON} - \sin 0}{2}\right]}$$

Here in this case,

t_{ON} = An integral number of input cycles; Hence

$$t_{ON} = T, 2T, 3T, 4T, 5T, ...\quad \&$$

$$\omega t_{ON} = 2\pi, 4\pi, 6\pi, 8\pi, 10\pi, ...$$

$$V_{O(RMS)} = \sqrt{\frac{V_m^{\,2}\,\cancel{\omega} t_{ON}}{2\cancel{\omega} T_O}} = \frac{V_m}{\sqrt{2}}\sqrt{\frac{t_{ON}}{T_O}}$$

$$V_{O(RMS)} = V_{i(RMS)}\sqrt{\frac{t_{ON}}{T_O}} = V_S\sqrt{\frac{t_{ON}}{T_O}}$$

Where $V_{i(RMS)} = \dfrac{V_m}{\sqrt{2}} = V_S$

$$\frac{t_{ON}}{T_O} = \frac{t_{ON}}{t_{ON} + t_{OFF}}$$

$$= \frac{nT}{nT + mT} = \frac{n}{(n+m)} = k$$

$$V_{O(RMS)} = V_S \sqrt{\frac{n}{(m+n)}} = V_S \sqrt{k}$$

RMS Out put voltage

$$V_{O(RMS)} = \left[\frac{n}{2\pi(n+m)} \int_0^{2\pi} V_m^{\ 2} \sin^2 \omega t . d(\omega t) \right]^{1/2}$$

$$V_{O(RMS)} = \frac{V_m}{\sqrt{2}} \sqrt{\frac{n}{(m+n)}} = V_{i(RMS)} \sqrt{k} = V_S \sqrt{k}$$

$$V_{O(RMS)} = V_{i(RMS)} \sqrt{k} = V_S \sqrt{k}$$

Duty cycle

$$k = \frac{t_{ON}}{T_O} = \frac{t_{ON}}{\left(t_{ON} + t_{OFF}\right)} = \frac{nT}{(m+n)T}$$

$$k = \frac{n}{(m+n)}$$

RMS Load Current

$$I_{O(RMS)} = \frac{V_{O(RMS)}}{Z} = \frac{V_{O(RMS)}}{R_L}$$

Output AC (Load) Power

$$P_O = I^2_{O(RMS)} \times R_L$$

Input Power factor

$$PF = \frac{P_O}{VA} = \frac{\text{output load power}}{\text{input supply volt amperes}} = \frac{P_O}{V_S I_S}$$

$$PF = \frac{I^2_{O(RMS)} \times R_L}{V_{i(RMS)} \times I_{in(RMS)}}$$

$$I_S = I_{in(RMS)} = \text{RMS input supply current.}$$

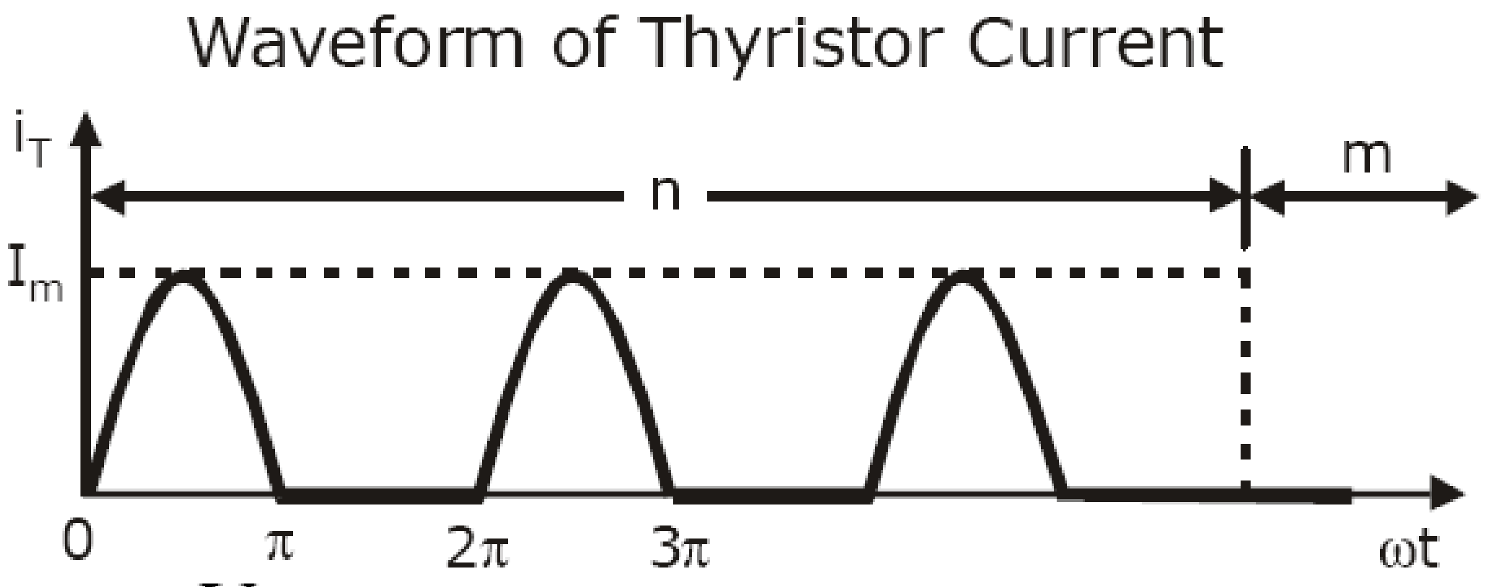
$$= \text{same as RMS load current } \mathrm{I_{O(RMS)}}$$

$$PF = \frac{I^2_{O(RMS)} \times R_L}{V_{i(RMS)} \times I_{in(RMS)}} = \frac{V_{O(RMS)}}{V_{i(RMS)}}$$

$$= \frac{V_{i(RMS)}\sqrt{k}}{V_{i(RMS)}} = \sqrt{k}$$

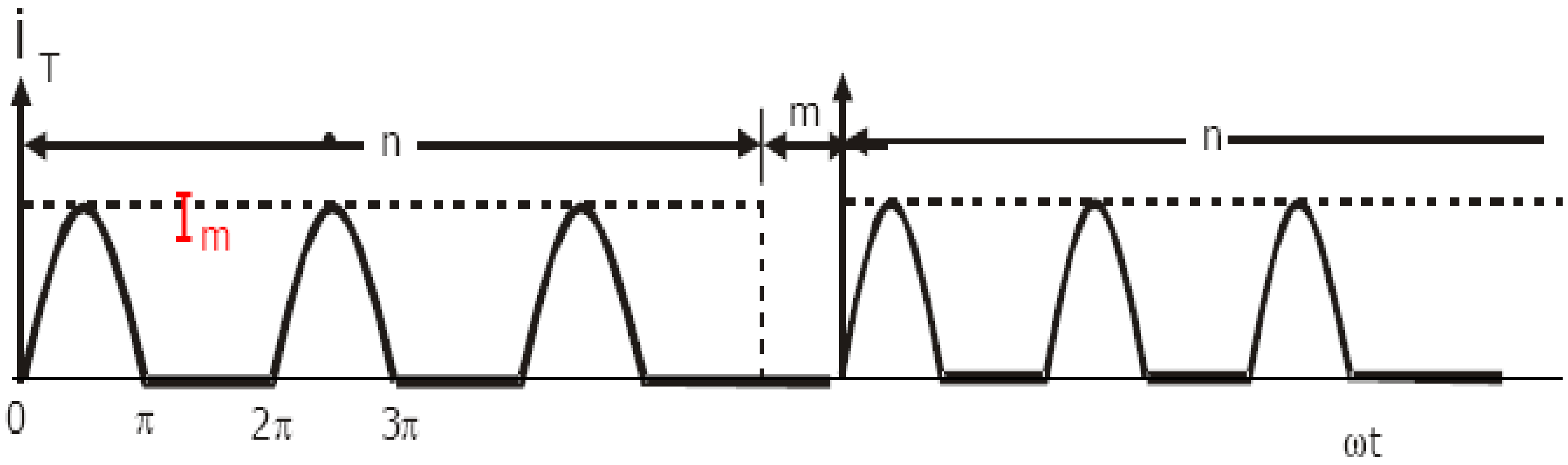
$$PF = \sqrt{k} = \sqrt{\frac{n}{m+n}}$$

The Average Current Of Thyristor



$$I_m = \frac{V_m}{R_L} = \text{max. or peak thyristor current}$$

Waveform of Thyristor current



$$I_{T(Avg)} = \frac{n}{2\pi(m+n)} \int_{0}^{\pi} I_m \sin \omega t . d(\omega t)$$

$$I_{T(Avg)} = \left(\frac{I_m}{\pi}\right) \frac{n}{(n+m)}$$

$$I_{T(Avg)} = \left(\frac{I_m}{\pi}\right) k$$

RMS Thyristor Current

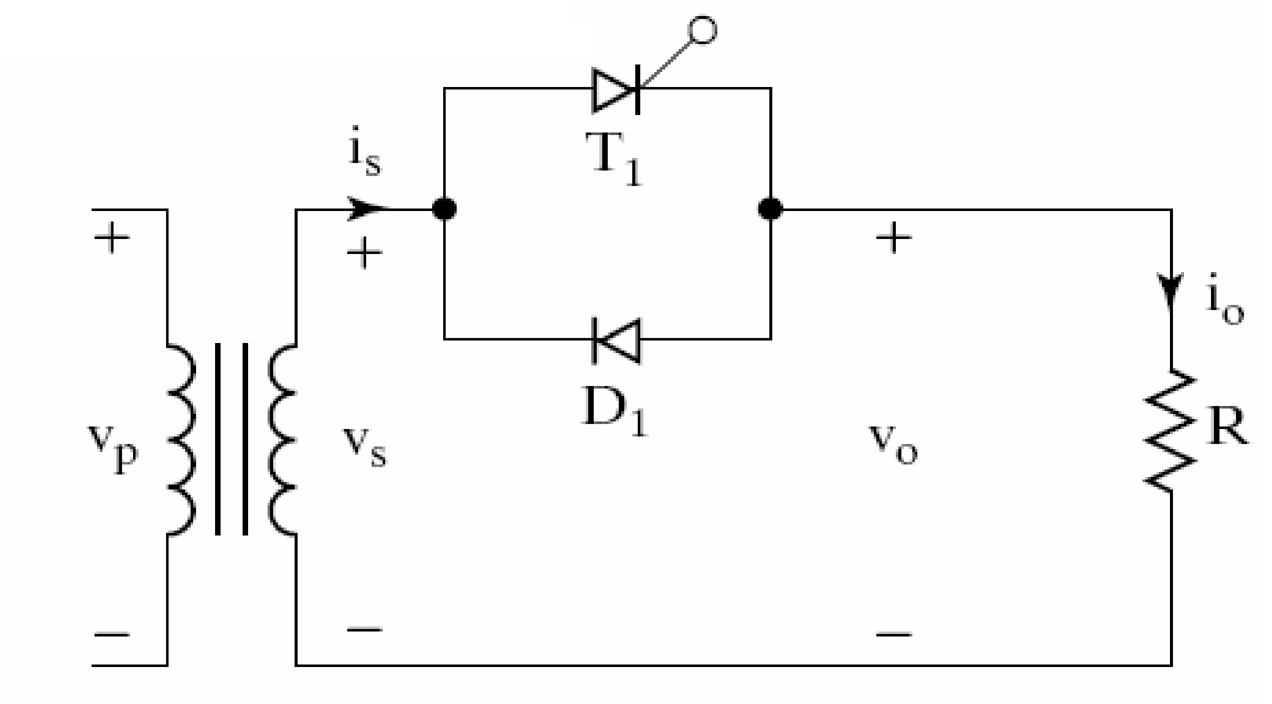
$$I_{T(RMS)} = \left[\frac{n}{2\pi(n+m)} \int_0^{\pi} I_m^2 \sin^2 \omega t . d(\omega t) \right]^{1/2}$$

$$I_{T(RMS)} = \frac{I_m}{2} \sqrt{\frac{n}{(m+n)}} = \frac{I_m}{2} \sqrt{k}$$

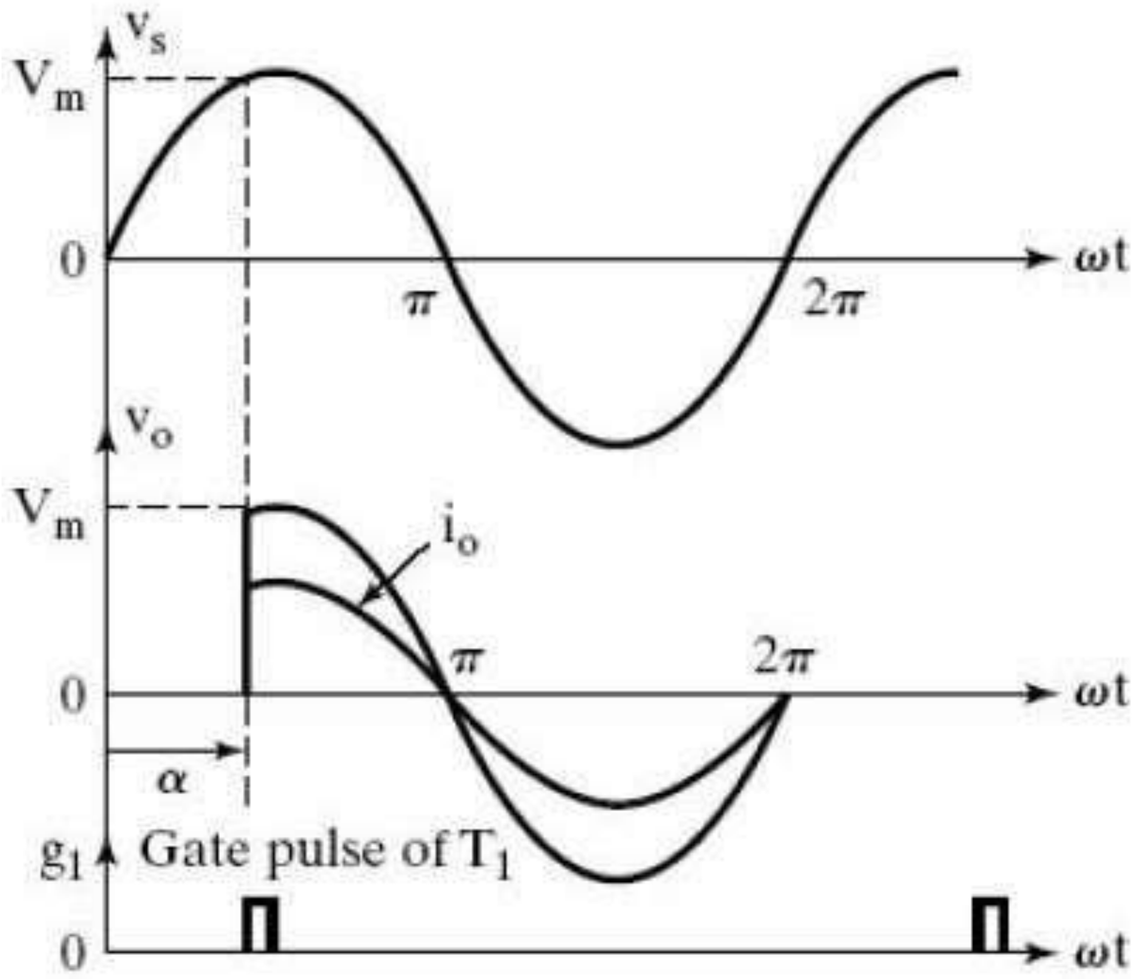
$$I_{T(RMS)} = \frac{I_m}{2} \sqrt{k}$$

Principle Of AC Phase Control
And
Operation of single Phase half-Wave A.C Phase controller

Principle Of AC Phase Control



Single phase Half-wave AC phase controller (Unidirectional Controller)



v_s
V_m
0
ωt
π
2π
v_o
V_m
i_o
π
2π
0
ωt
α
g_1 Gate pulse of T_1
0
ωt

Equations

- **Input AC Supply Voltage**

$$v_s = V_m \sin \omega t$$

$$V_S = V_{in(RMS)} = \frac{V_m}{\sqrt{2}} = \text{RMS value of}$$

input supply voltage

Output Load Voltage

$$v_o = v_L = 0;$$

$$\text{for } \omega t = 0 \text{ to } \alpha$$

$$v_o = v_L = V_m \sin \omega t;$$

$$\text{for } \omega t = \alpha \text{ to } 2\pi$$

Out Put Load Current

$$i_o = i_L = \frac{v_o}{R_L} = \frac{V_m \sin \omega t}{R_L} = I_m \sin \omega t \;\; ;$$

$$\text{for } \omega t = \alpha \text{ to } 2\pi$$

$$i_o = i_L = 0;$$

$$\text{for } \omega t = 0 \text{ to } \alpha$$

Expression For RMS Out put Load Voltage

$$V_{O(RMS)} = \sqrt{\frac{1}{2\pi}\left[\int_{\alpha}^{2\pi} V_m^{\ 2} \sin^2 \omega t.d\left(\omega t\right)\right]}$$

$$V_{O(RMS)} = \sqrt{\frac{V_m^{\ 2}}{2\pi}\left[\int_{\alpha}^{2\pi}\left(\frac{1-\cos 2\omega t}{2}\right).d\left(\omega t\right)\right]}$$

$$V_{O(RMS)} = \sqrt{\frac{V_m^{\ 2}}{4\pi}\left[\int_{\alpha}^{2\pi}\left(1-\cos 2\omega t\right).d\left(\omega t\right)\right]}$$

$$V_{O(RMS)} = \frac{V_m}{2\sqrt{\pi}}\sqrt{\left[\int_{\alpha}^{2\pi} d\left(\omega t\right) - \int_{\alpha}^{2\pi} \cos 2\omega t.d\,\omega t\right]}$$

$$V_{O(RMS)} = \frac{V_m}{2\sqrt{\pi}}\sqrt{\left[\left(\omega t\right)\Big/_{\alpha}^{2\pi} - \left(\frac{\sin 2\omega t}{2}\right)\Big/_{\alpha}^{2\pi}\right]}$$

$$V_{O(RMS)} = \frac{V_m}{2\sqrt{\pi}} \sqrt{(2\pi - \alpha) - \left(\frac{\sin 2\omega t}{2} \right) \Big/_{\alpha}^{2\pi}}$$

$$V_{O(RMS)} = \frac{V_m}{2\sqrt{\pi}} \sqrt{(2\pi - \alpha) - \left\{ \frac{\sin 4\pi}{2} - \frac{\sin 2\alpha}{2} \right\}}$$

$$V_{O(RMS)} = \frac{V_m}{2\sqrt{\pi}} \sqrt{(2\pi - \alpha) + \frac{\sin 2\alpha}{2}}$$

$$V_{O(RMS)} = \frac{V_m}{\sqrt{2}\sqrt{2\pi}}\sqrt{(2\pi - \alpha) + \frac{\sin 2\alpha}{2}}$$

$$V_{O(RMS)} = \frac{V_m}{\sqrt{2}}\sqrt{\frac{1}{2\pi}\left[(2\pi - \alpha) + \frac{\sin 2\alpha}{2}\right]}$$

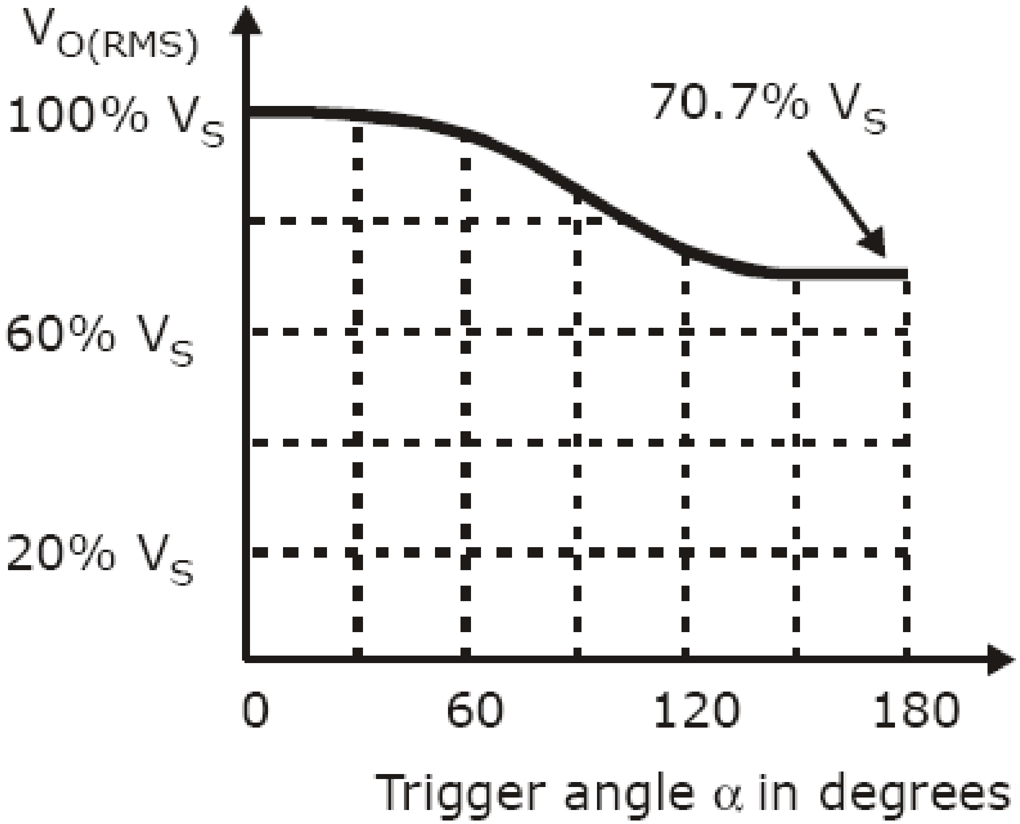
$$V_{O(RMS)} = V_{i(RMS)}\sqrt{\frac{1}{2\pi}\left[(2\pi - \alpha) + \frac{\sin 2\alpha}{2}\right]}$$

$$V_{O(RMS)} = V_S \sqrt{\frac{1}{2\pi}\left[(2\pi - \alpha) + \frac{\sin 2\alpha}{2}\right]}$$

where $V_{i(RMS)} = V_S = \frac{V_m}{\sqrt{2}} =$

RMS value of input supply voltage

Control Characteristics



Average Value of Out put Voltage

$$V_{O(dc)} = \frac{1}{2\pi} \int_{\alpha}^{2\pi} V_m \sin \omega t . d(\omega t)$$

$$V_{O(dc)} = \frac{V_m}{2\pi} \int_{\alpha}^{2\pi} \sin \omega t . d(\omega t)$$

$$V_{O(dc)} = \frac{V_m}{2\pi}\left[-\cos\omega t \Big/_{\alpha}^{2\pi}\right]$$

$$V_{O(dc)} = \frac{V_m}{2\pi}\left[-\cos 2\pi + \cos\alpha\right] \; ; \; \cos 2\pi = 1$$

$$V_{dc} = \frac{V_m}{2\pi}\left[\cos\alpha - 1\right] \; ; \; V_m = \sqrt{2}V_S$$

Hence,

$$V_{dc} = \frac{\sqrt{2}V_S}{2\pi}(\cos\alpha - 1)$$

When α is varied from 0 to π

V_{dc} varies from 0 to $\frac{-V_m}{\pi}$

Disadvantages

- Output load voltage has a DC component as the two halves are not symmetrical with respect to ‘0’ level.
- Limited range of RMS output voltage control from 100% of V_S to 70.7% of V_S, when we vary the trigger angle from zero to 180 degrees.

Single Phase Full Wave Ac Voltage Controller (Bidirectional Controller) With R-Load

Single Phase Full Wave Ac Voltage Controller With R-Load

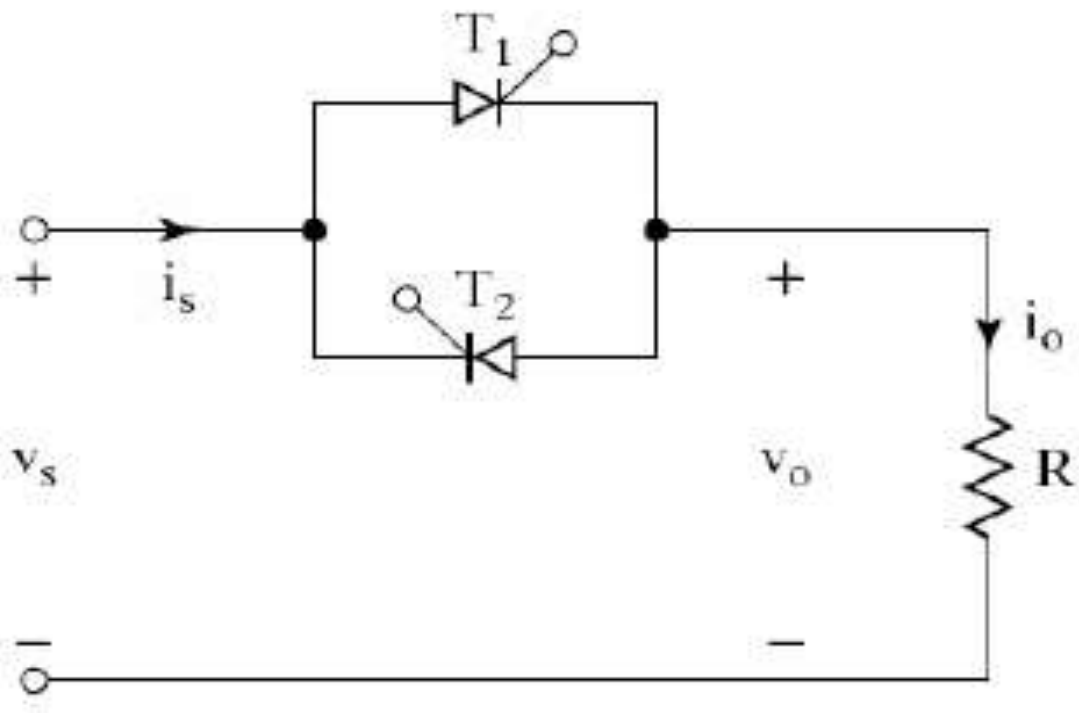
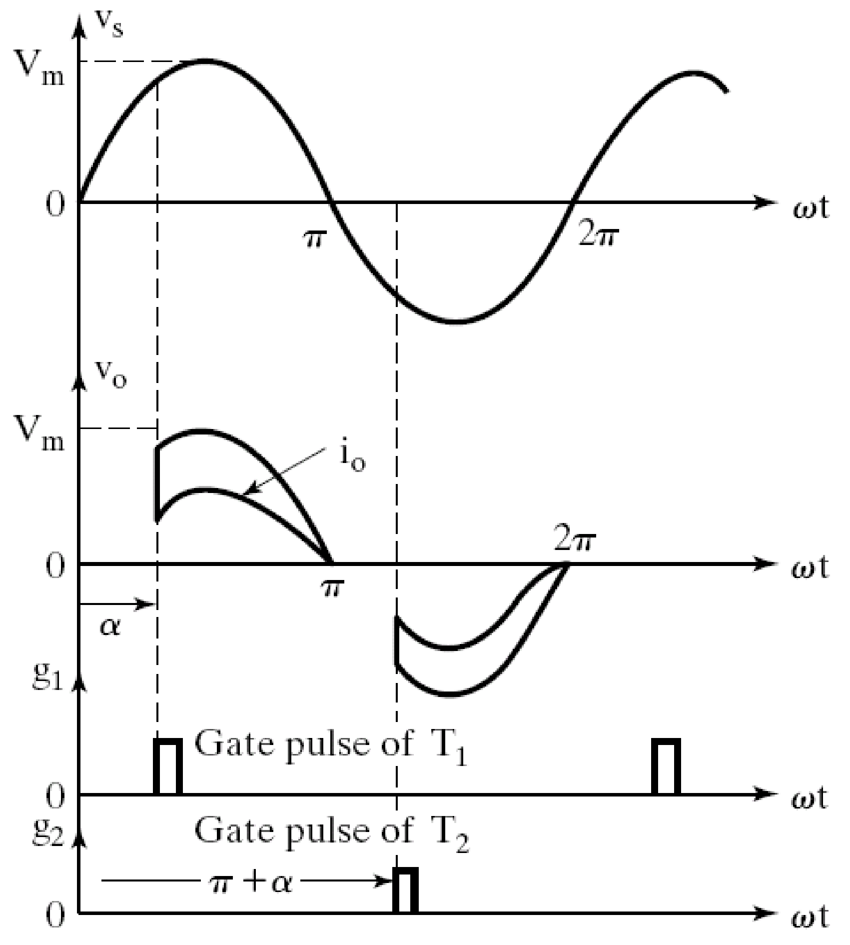


Fig.: Single phase full wave ac voltage controller (Bi-directional Controller) using SCR

Waveforms of single phase full wave ac voltage controller



Expression for RMS output voltage

$$V^2_{L(RMS)} = \frac{1}{\pi}\int_0^{\pi} V_m^{\,2}\sin^2\omega t.d\omega t$$

$$V^2_{L(RMS)} = \frac{1}{2\pi}\int_0^{2\pi} v_L^{\,2}.d(\omega t)$$

$$V^2_{L(RMS)} = \frac{1}{2\pi}\left[\int_{\alpha}^{\pi}(V_m\sin\omega t)^2 d(\omega t) + \int_{\pi+\alpha}^{2\pi}(V_m\sin\omega t)^2 d(\omega t)\right]$$

Contd…

$$=\frac{1}{2\pi}\left[V_m{}^2\int_{\alpha}^{\pi}\sin^2\omega t.d\left(\omega t\right)+V_m{}^2\int_{\pi+\alpha}^{2\pi}\sin^2\omega t.d\left(\omega t\right)\right]$$

$$=\frac{1}{2\pi}\left[V_m{}^2\int_{\alpha}^{\pi}\sin^2\omega t.d\left(\omega t\right)+V_m{}^2\int_{\pi+\alpha}^{2\pi}\sin^2\omega t.d\left(\omega t\right)\right]$$

$$=\frac{V_m{}^2}{2\pi}\left[\int_{\alpha}^{\pi}\frac{1-\cos 2\omega t}{2}d\left(\omega t\right)+\int_{\pi+\alpha}^{2\pi}\frac{1-\cos 2\omega t}{2}d\left(\omega t\right)\right]$$

$$=\frac{V_m{}^2}{2\pi\times 2}\left[\int_{\alpha}^{\pi}d\left(\omega t\right)-\int_{\alpha}^{\pi}\cos 2\omega t.d\left(\omega t\right)+\int_{\pi+\alpha}^{2\pi}d\left(\omega t\right)-\int_{\pi+\alpha}^{2\pi}\cos 2\omega t.d\left(\omega t\right)\right]$$

$$=\frac{V_m^{\;2}}{4\pi}\left[\left(\omega t\right)\Big/_{\alpha}^{\pi}+\left(\omega t\right)\Big/_{\pi+\alpha}^{2\pi}-\left[\frac{\sin 2\omega t}{2}\right]_{\alpha}^{\pi}-\left[\frac{\sin 2\omega t}{2}\right]_{\pi+\alpha}^{2\pi}\right]$$

$$=\frac{V_m^{\;2}}{4\pi}\left[\left(\pi-\alpha\right)+\left(\pi-\alpha\right)-\frac{1}{2}\left(\sin 2\pi-\sin 2\alpha\right)-\frac{1}{2}\left(\sin 4\pi-\sin 2\left(\pi+\alpha\right)\right)\right]$$

$$=\frac{V_m{}_2}{4\pi}\left[2\left(\pi-\alpha\right)-\frac{1}{2}\left(0-\sin 2\alpha\right)-\frac{1}{2}\left(0-\sin 2\left(\pi+\alpha\right)\right)\right]$$

$$=\frac{V_m^{\;2}}{4\pi}\left[2\left(\pi-\alpha\right)+\frac{\sin 2\alpha}{2}+\frac{\sin 2\left(\pi+\alpha\right)}{2}\right]$$

$$= \frac{V_m^2}{4\pi}\left[2(\pi-\alpha)+\frac{\sin 2\alpha}{2}+\frac{\sin(2\pi+2\alpha)}{2}\right]$$

$$= \frac{V_m^2}{4\pi}\left[2(\pi-\alpha)+\frac{\sin 2\alpha}{2}+\frac{1}{2}(\sin 2\pi.\cos 2\alpha+\cos 2\pi.\sin 2\alpha)\right]$$

$$\sin 2\pi = 0 \quad \& \quad \cos 2\pi = 1$$

Therefore,

$$V_{L(RMS)}^2 = \frac{V_m^2}{4\pi}\left[2(\pi-\alpha)+\frac{\sin 2\alpha}{2}+\frac{\sin 2\alpha}{2}\right]$$

$$V_{L(RMS)}^2 = \frac{V_m^2}{4\pi}\left[(2\pi-2\alpha)+\sin 2\alpha\right]$$

- Taking the square root, we get

$$V_{L(RMS)} = \frac{V_m}{2\sqrt{\pi}}\sqrt{\left[\left(2\pi - 2\alpha\right) + \sin 2\alpha\right]}$$

$$V_{L(RMS)} = \frac{V_m}{\sqrt{2}\sqrt{2\pi}}\sqrt{\left[\left(2\pi - 2\alpha\right) + \sin 2\alpha\right]}$$

$$V_{L(RMS)} = \frac{V_m}{\sqrt{2}}\sqrt{\frac{1}{2\pi}\left[\left(2\pi - 2\alpha\right) + \sin 2\alpha\right]}$$

$$V_{L(RMS)} = \frac{V_m}{\sqrt{2}}\sqrt{\frac{1}{2\pi}\left[2\left\{\left(\pi - \alpha\right) + \frac{\sin 2\alpha}{2}\right\}\right]}$$

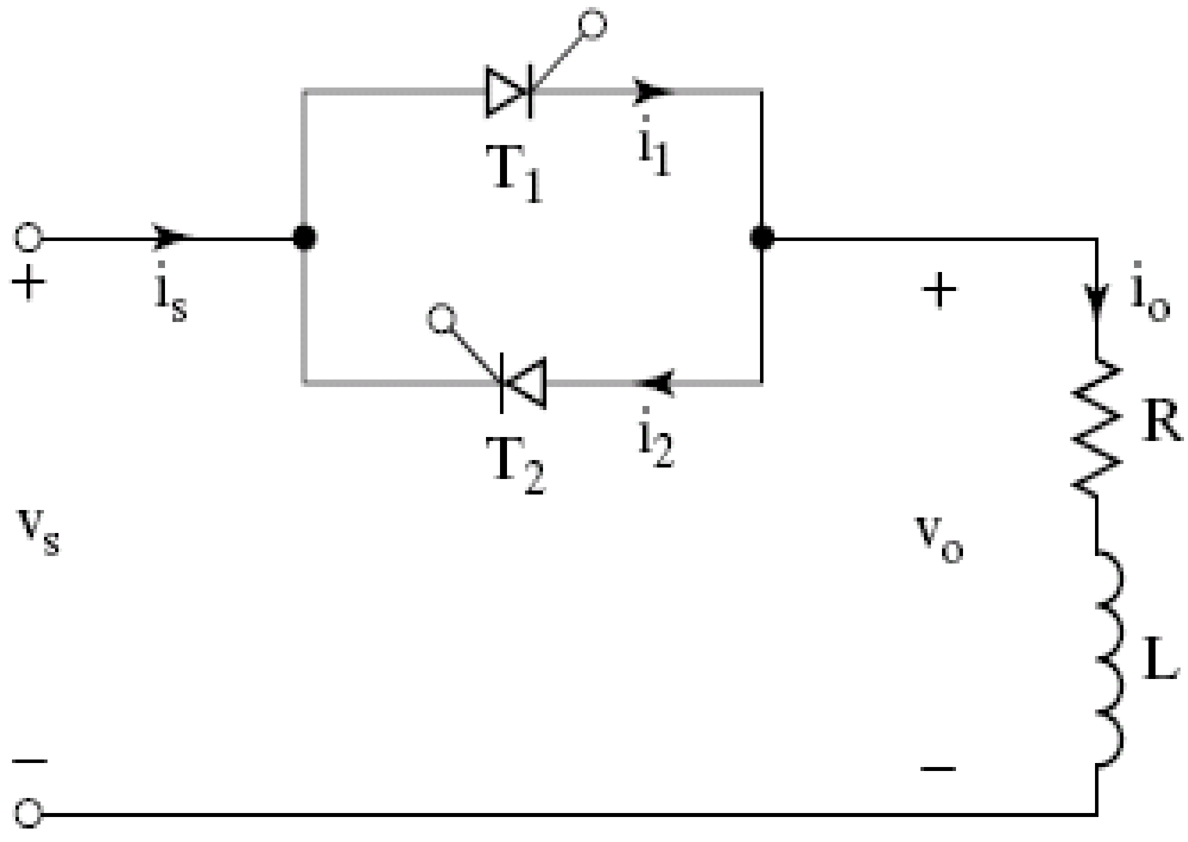
$$V_{L(RMS)} = \frac{V_m}{\sqrt{2}} \sqrt{\frac{1}{\pi}\left[(\pi - \alpha) + \frac{\sin 2\alpha}{2}\right]}$$

$$V_{L(RMS)} = V_{i(RMS)} \sqrt{\frac{1}{\pi}\left[(\pi - \alpha) + \frac{\sin 2\alpha}{2}\right]}$$

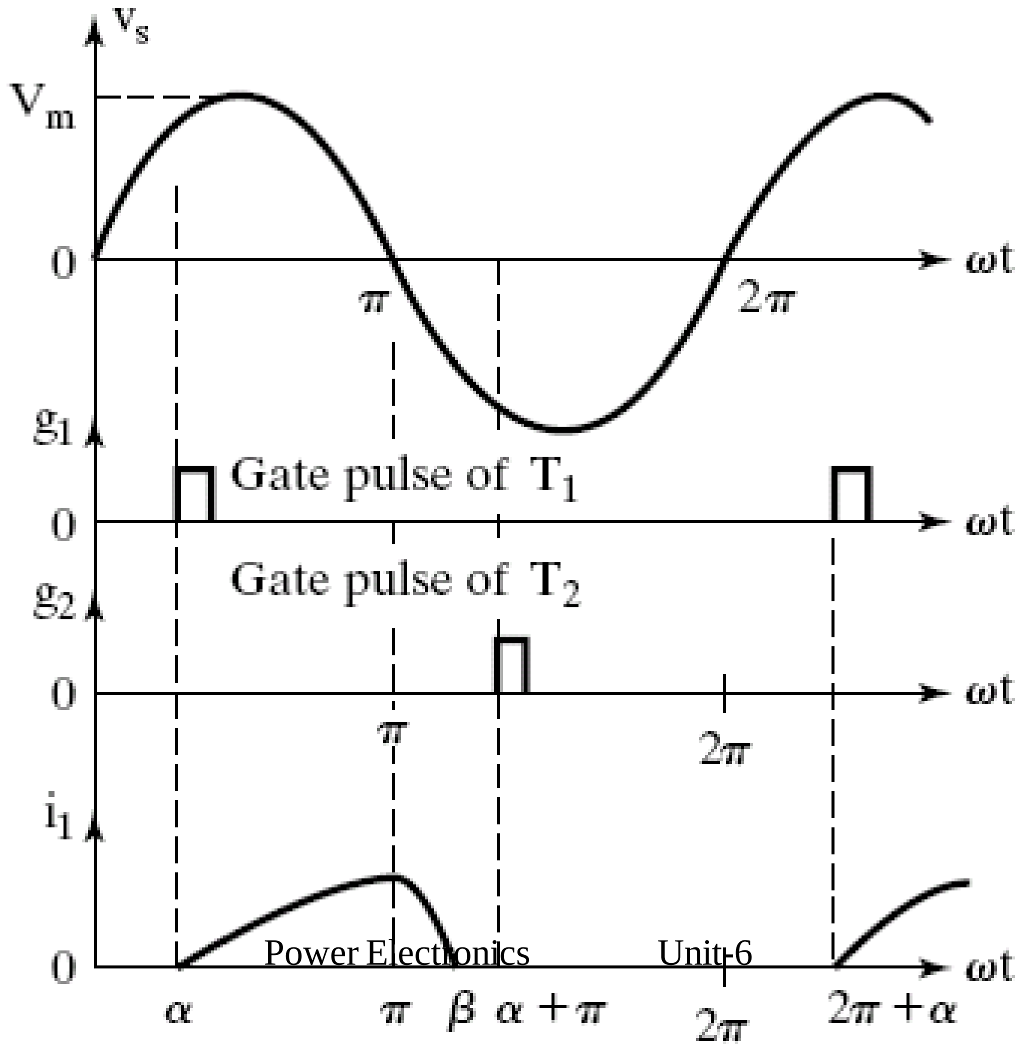
$$V_{L(RMS)} = V_S \sqrt{\frac{1}{\pi}\left[(\pi - \alpha) + \frac{\sin 2\alpha}{2}\right]}$$

Single Phase Full Wave Ac Voltage Controller (Bidirectional Controller) With R-L Load

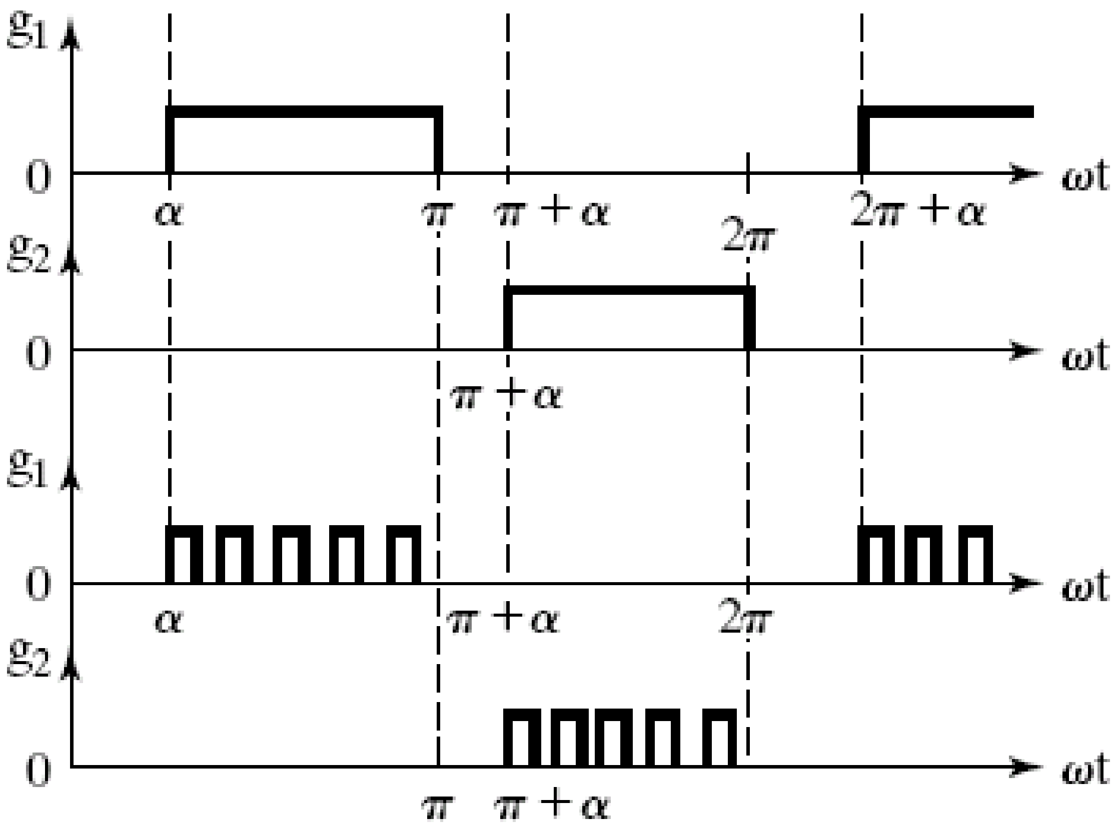
Single Phase Full Wave Ac Voltage Controller (Bidirectional Controller) With R-L Load



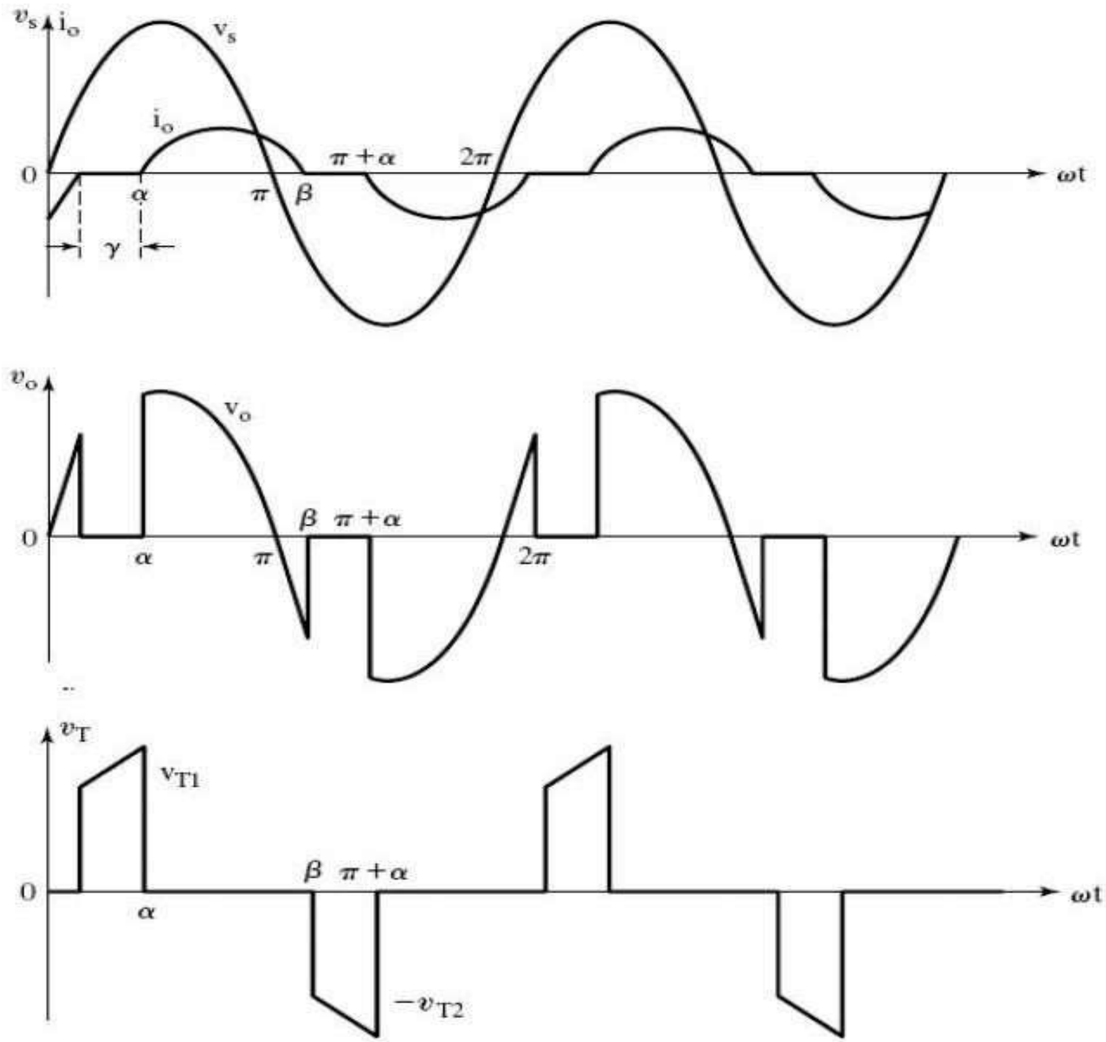
Input supply voltage & Thyristor current waveforms



Gating Signals



Waveforms For RL load for $\alpha > \phi$ and for Discontinuous Conduction



Expression for the inductive load current of a single phase full wave ac voltage controller with RL load

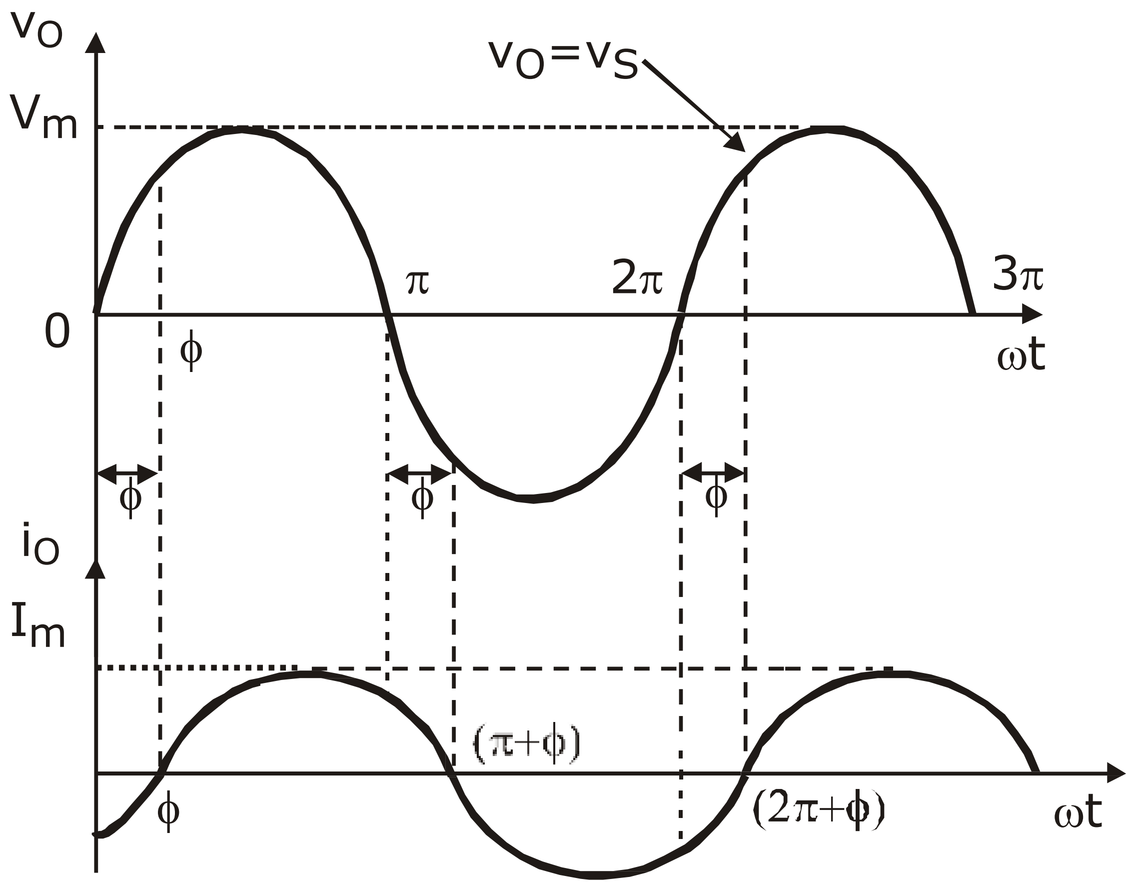
$$i_O = \frac{V_m}{Z}\left[\sin(\omega t - \phi) - \sin(\alpha - \phi) e^{\frac{-R}{\omega L}(\omega t - \alpha)}\right]$$

Where $Z = \sqrt{R^2 + (\omega L)^2}$

$$\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$$

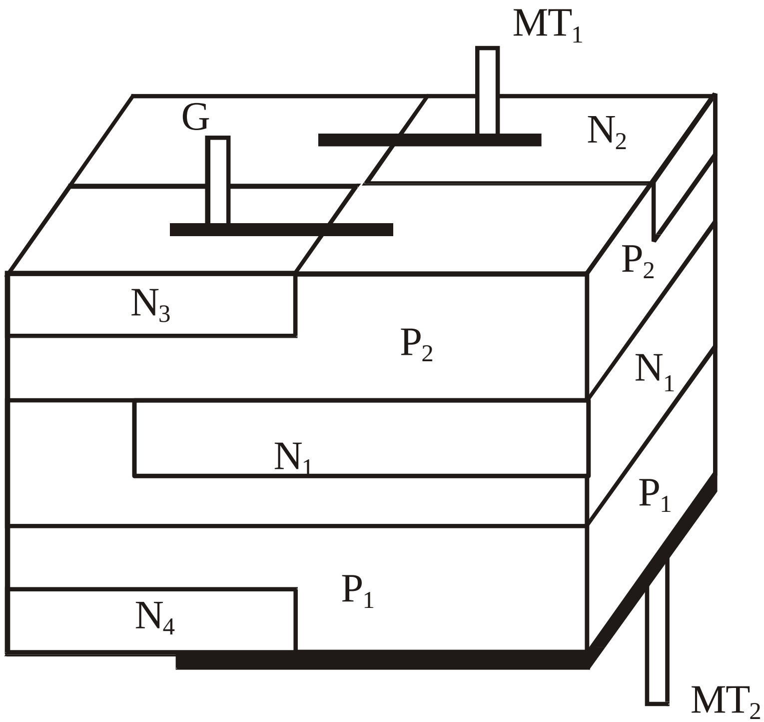
= Load impedance angle (power factor angle of load).

Output voltage and output current waveforms for a single phase full wave ac voltage controller with RL load for $\alpha \leq \phi$



TRIAC and Its Modes of Operation

TRIAC



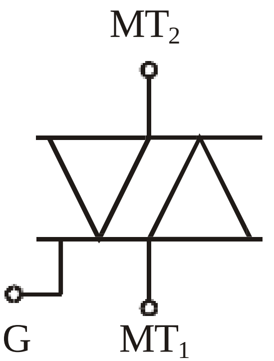
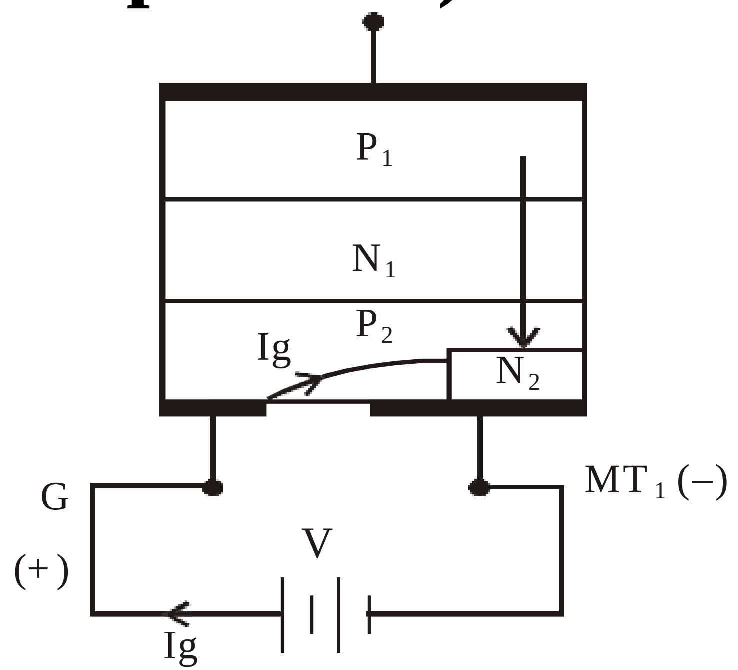


Fig.1 : Triac Structure Fig. 2 : Triac Symbol

TRIGGERING MODES OF TRIAC

- **MODE 1 : MT1 positive, Positive gate current (I^+ mode of operation)**

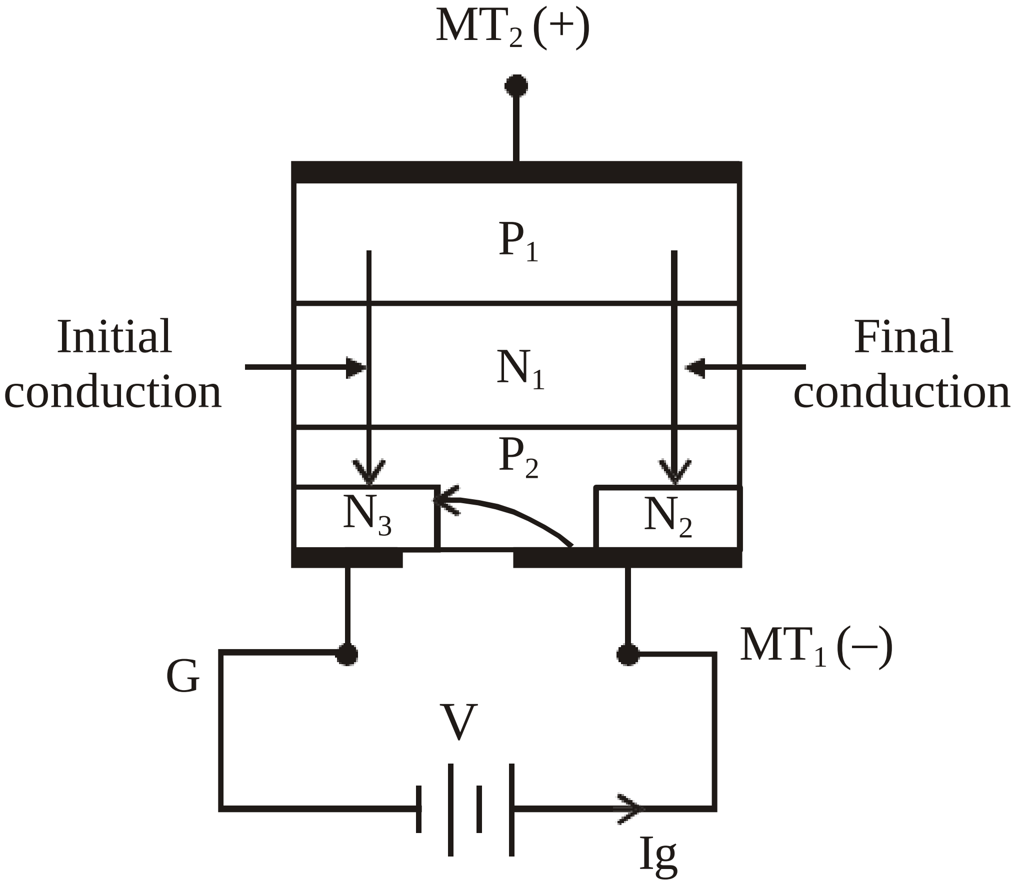


- When and gate current are positive with respect to MT1, the gate current flows through P2-N2 junction
- The junction P1-N1 and P2-N2 are forward biased but junction N1-P2 is reverse biased.
- When sufficient number of charge carriers are injected in P2 layer by the gate current the junction N1-P2 breakdown and triac starts conducting through P1N1P2N2 layers.
- Once triac starts conducting the current increases and its V-I characteristics is similar to that of thyristor. Triac in this mode operates in the first-quadrant.

MODE 2

- **MT2 positive, Negative gate current**

  (I^- mode of operation)

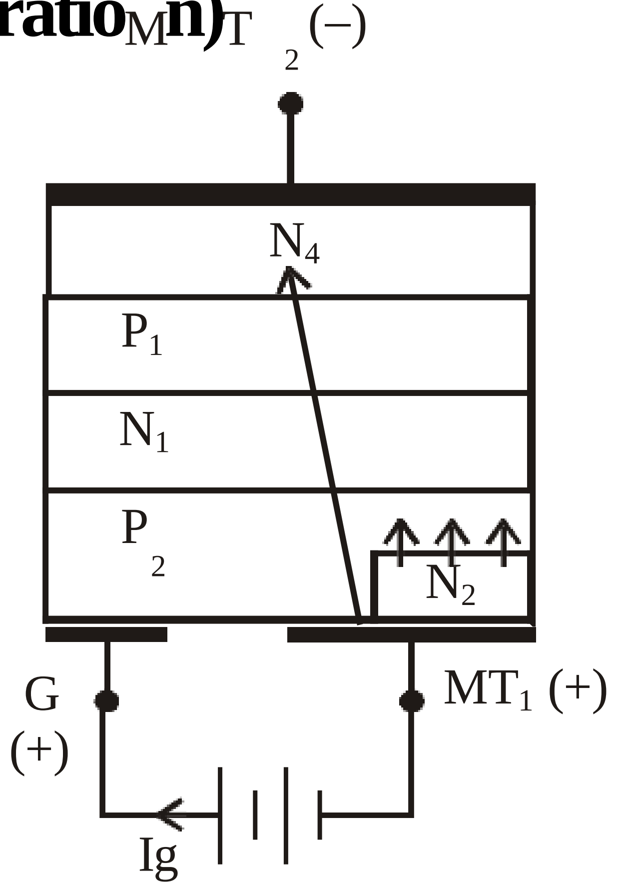


- When MT2 is positive and gate G is negative with respect to MT1 the gate current flows through P2-N3 junction
- The junction P1-N1 and P2-N3 are forward biased but junction N1-P2 is reverse biased. Hence, the triac initially starts conducting through P1N1P2N3 layers.
- As a result the potential of layer between P2-N3 rises towards the potential of MT2.
- Thus, a potential gradient exists across the layer P2 with left hand region at a higher potential than the right hand region.

- This results in a current flow in P2 layer from left to right, forward biasing the P2N2 junction. Now the right hand portion P1-N1 - P2-N2 starts conducting.
- The device operates in first quadrant. When compared to Mode 1, triac with MT2 positive and negative gate current is less sensitive and therefore requires higher gate current for triggering.

MODE 3

- **MT2 negative, Positive gate current (III^+ mode of operation)**

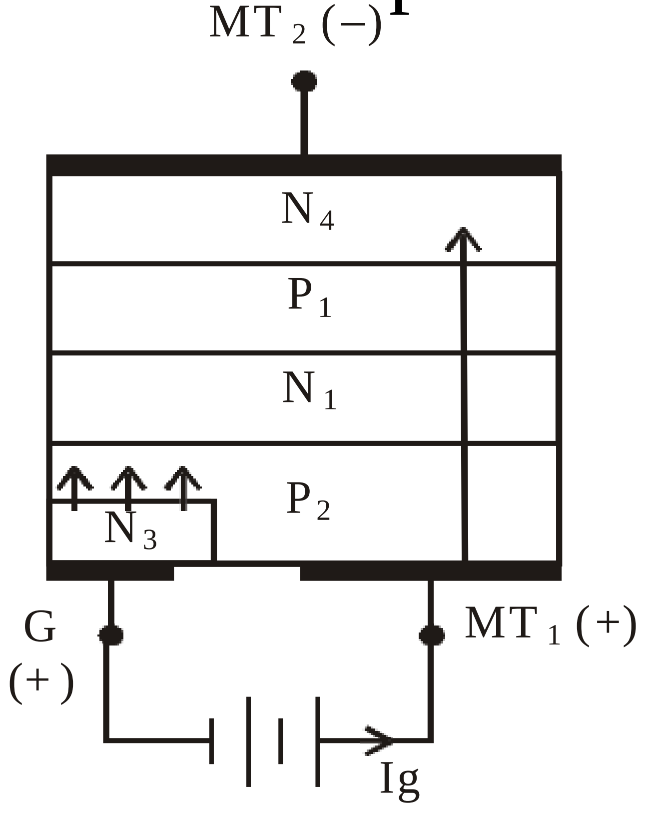


- When MT2 is negative and gate is positive with respect to MT1 junction P2N2 is forward biased and junction P1-N1 is reverse biased.
- N2 layer injects electrons into P2 layer as shown by arrows in figure below.
- This causes an increase in current flow through junction P2-N1. Resulting in breakdown of reverse biased junction N1-P1.
- Now the device conducts through layers P2N1P1N4 and the current starts increasing, which is limited by an external load.
- The device operates in third quadrant in this mode. Triac in this mode is less sensitive and requires higher gate current for triggering.

MODE 4

- **MT2 negative, Negative gate current**

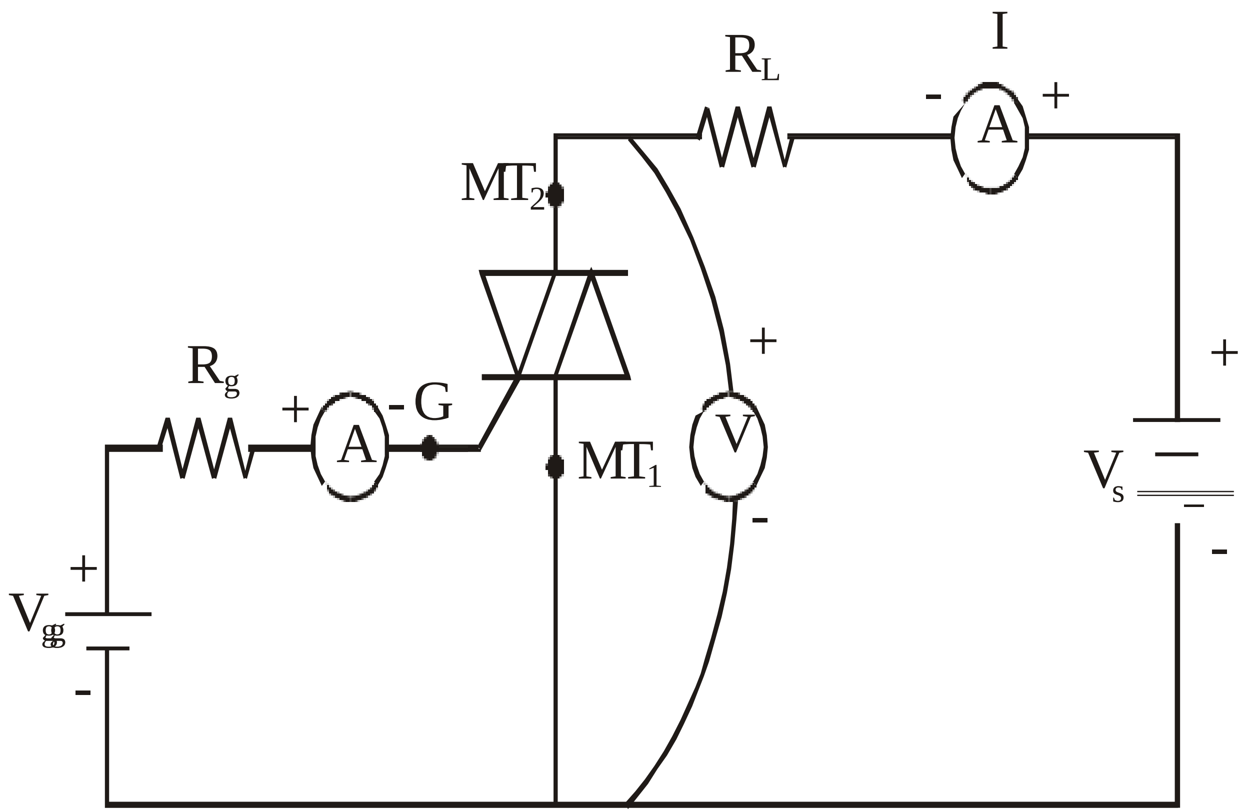
(III$^+$ mode of operation)



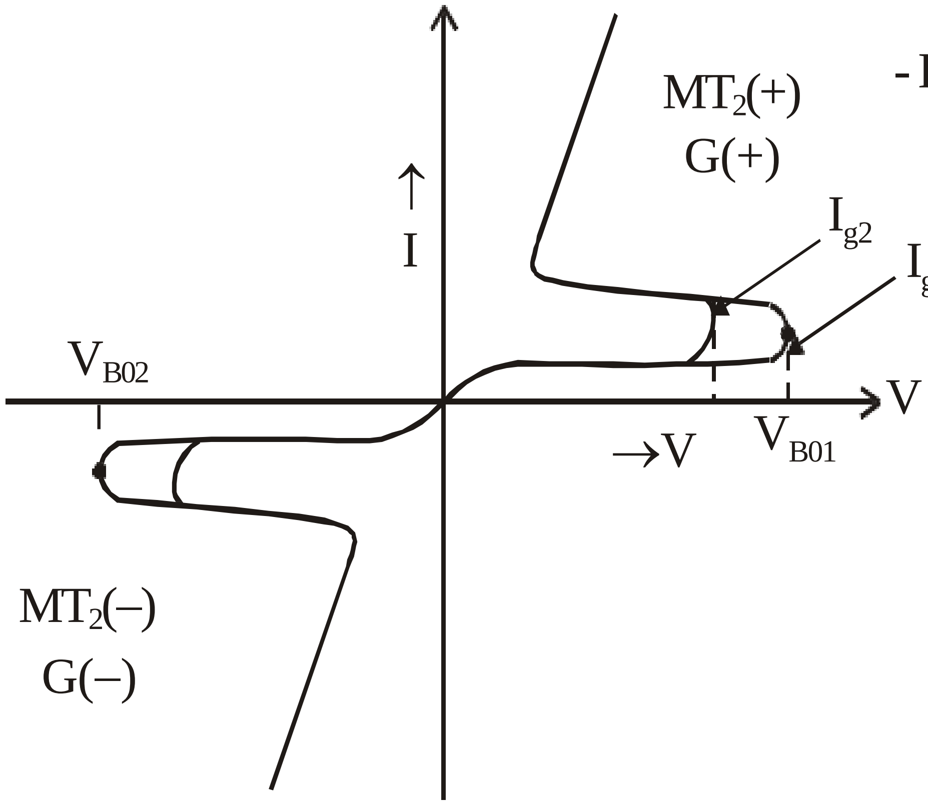
- In this mode both MT2 and gate G are negative with respect to MT1, the gate current flows through P2N3 junction as shown.
- Layer N3 injects electrons as shown by arrows into P2 layer. This results in increase in current flow across P1N1 and the device will turn ON due to increased current in layer N1.
- The current flows through layers P2N1P1N4. Triac is more sensitive in this mode compared to turn ON with positive gate current. (Mode 3).

- Triac sensitivity is greatest in the first quadrant when turned ON with positive gate current and also in third quadrant when turned ON with negative gate current. when is positive with respect to it is recommended to turn on the triac by a positive gate current.
- When is negative with respect to it is recommended to turn on the triac by negative gate current. Therefore Mode 1 and Mode 4 are the preferred modes of operation of a triac (mode and mode of operation are normally used).

Triac characteristics



V-I Characteristics of a triac



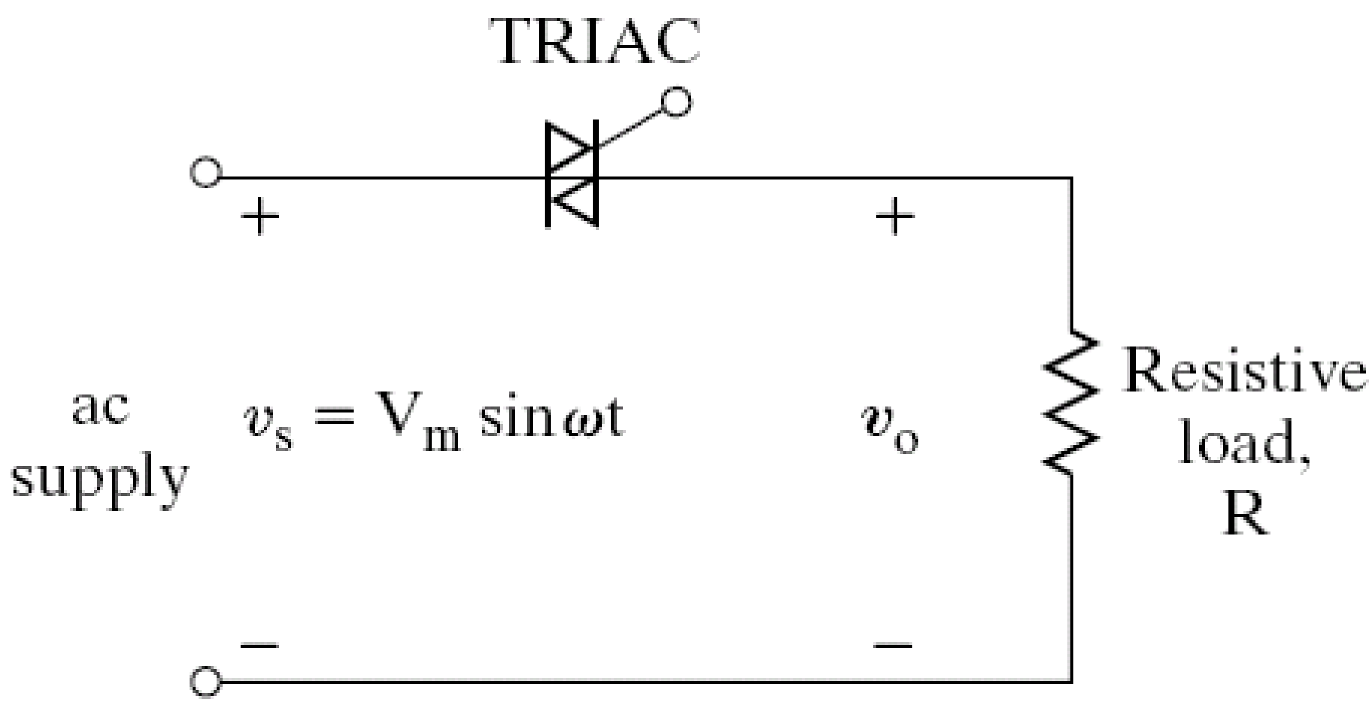
V_{B01}, V_{B01}
- Breakover voltages

$I_{g2} > I_{g21}$

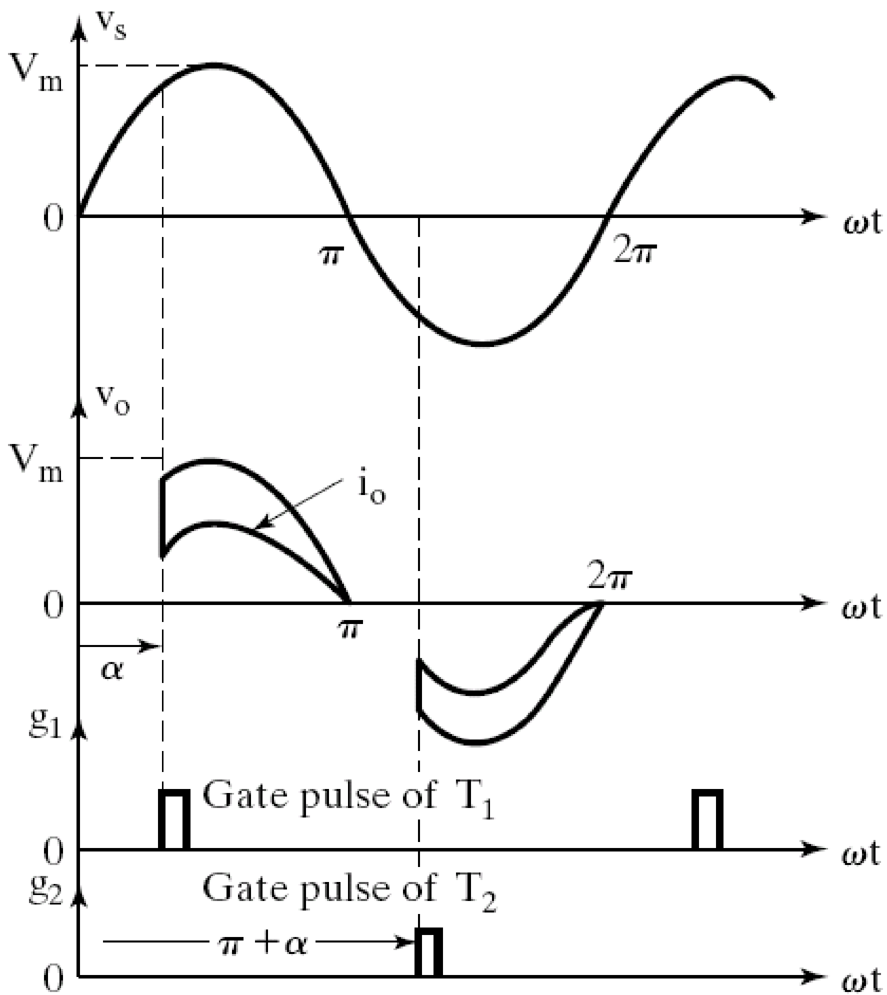
Single phase full wave ac voltage controller

(Bi-directional Controller) using TRIAC

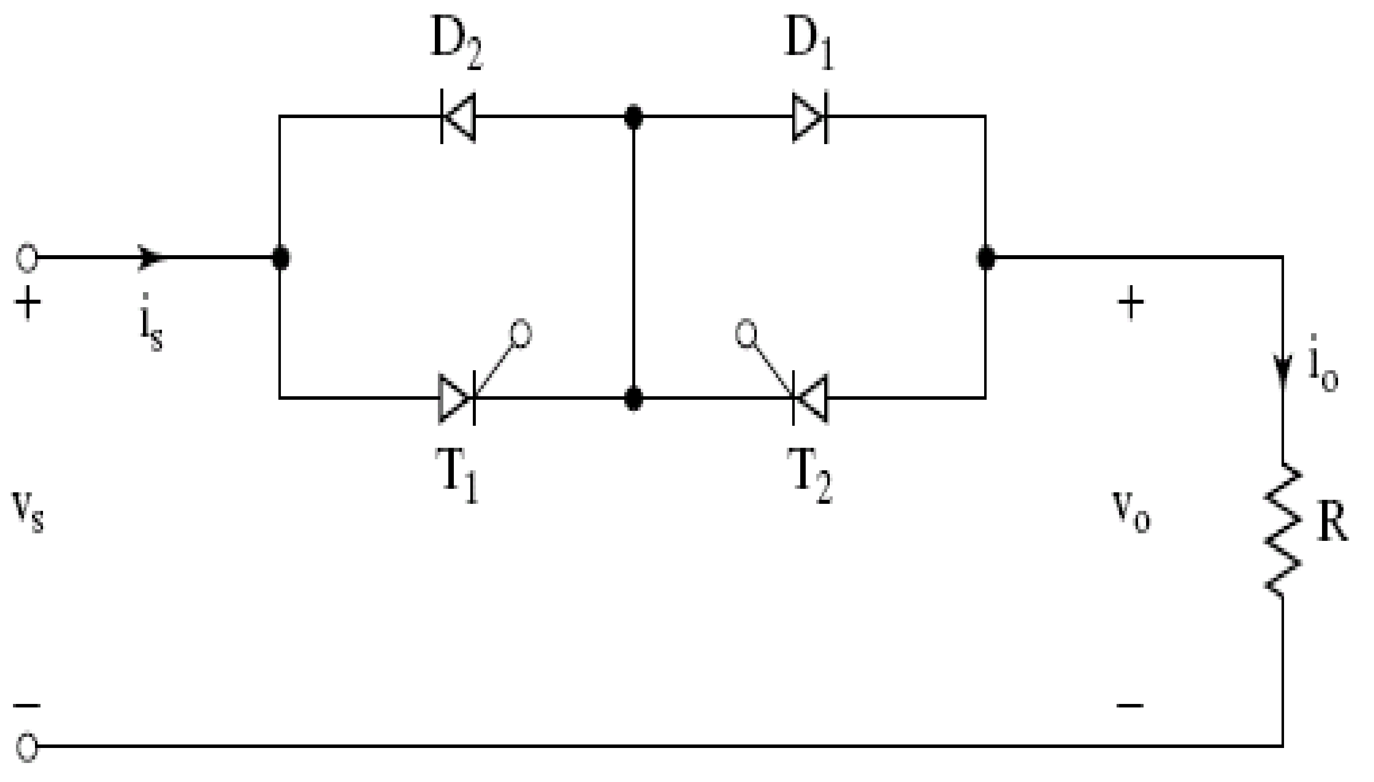
Single phase full wave ac voltage controller (Bi-directional Controller) using TRIAC



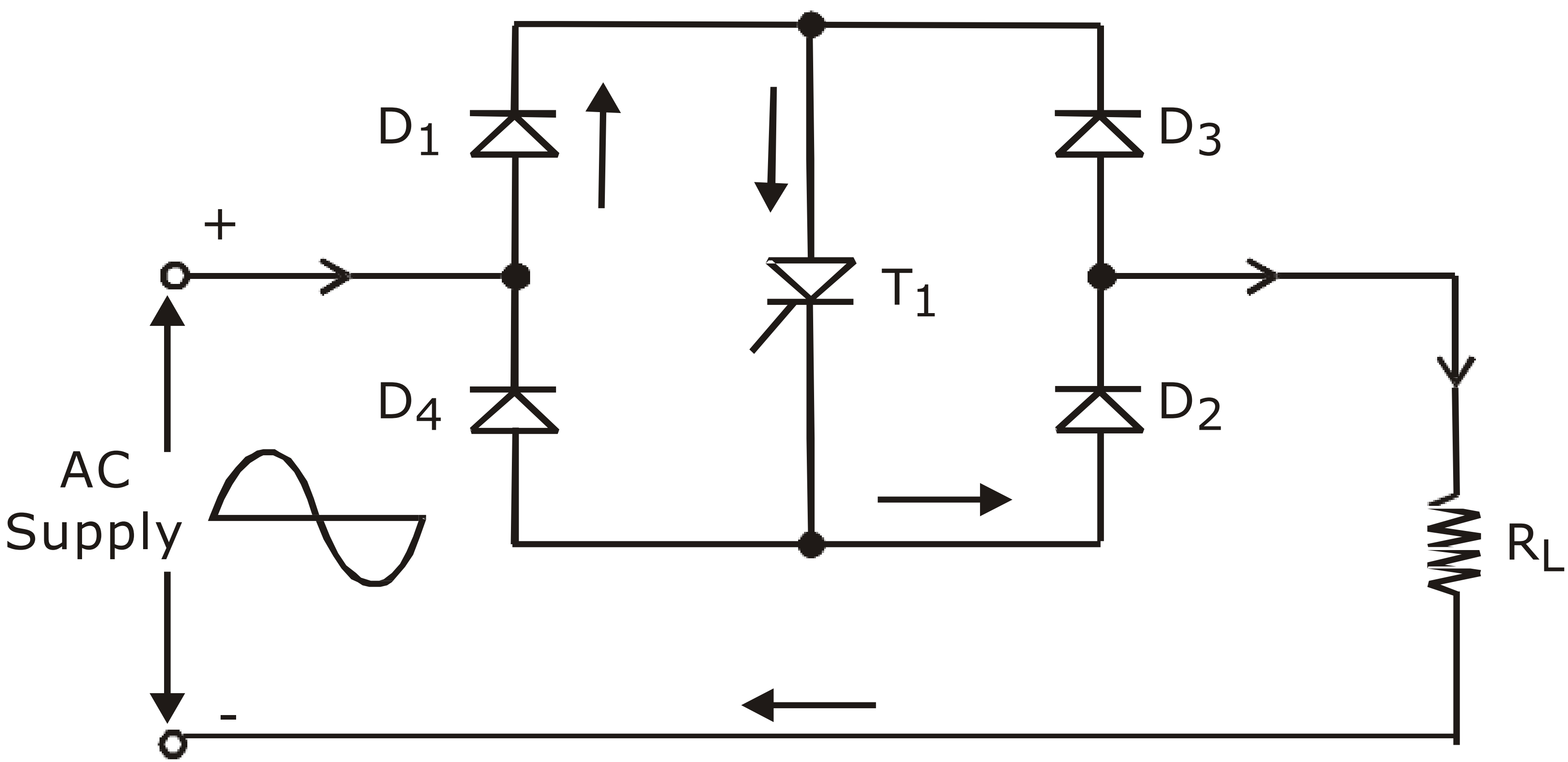
Waveforms of single phase full wa ... ller



Single phase full wave ac controller with common cathode (Bidirectional controller in common cathode configuration)



Single Phase Full Wave Ac Voltage Controller Using A Single Thyristor



CYCLOCONVERTER

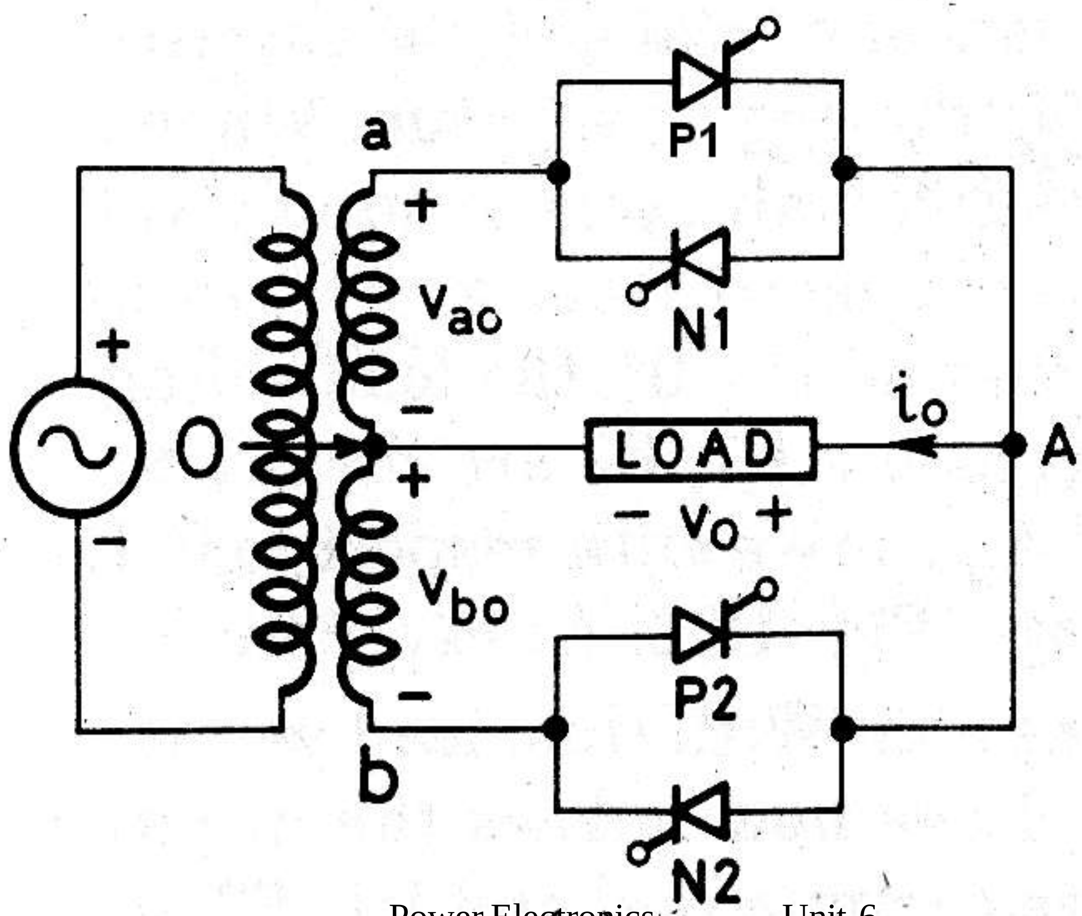
CYCLOCONVERTER

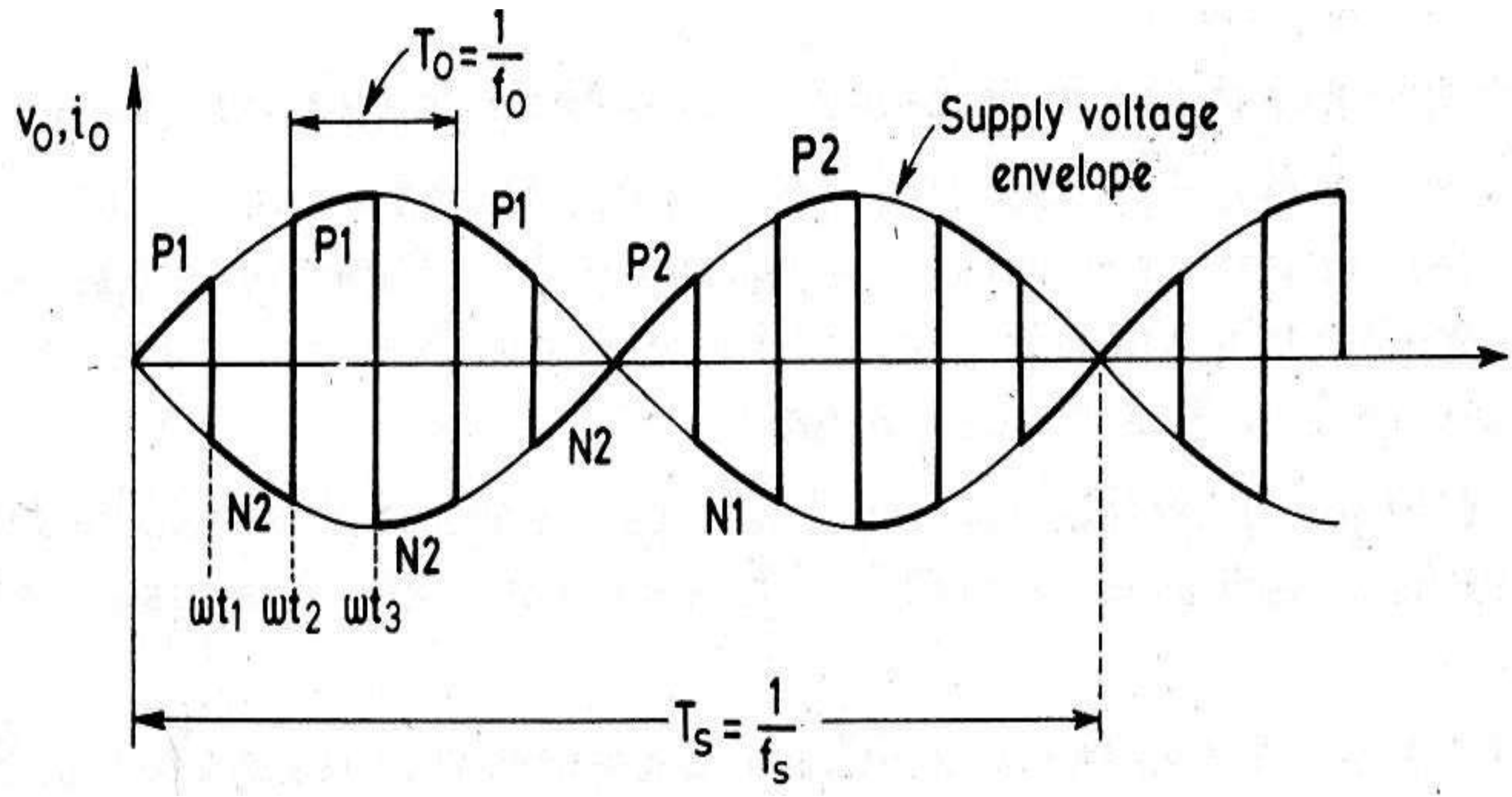
- A device which converts input power at one frequency to the out put power at different frequency with one stage conversion is called a cycloconverter.
- A cycloconverter requires one stage frequency conversion.
- Cycloconverter of two types

(i) Step-Up Cycloconverter (fo > s)

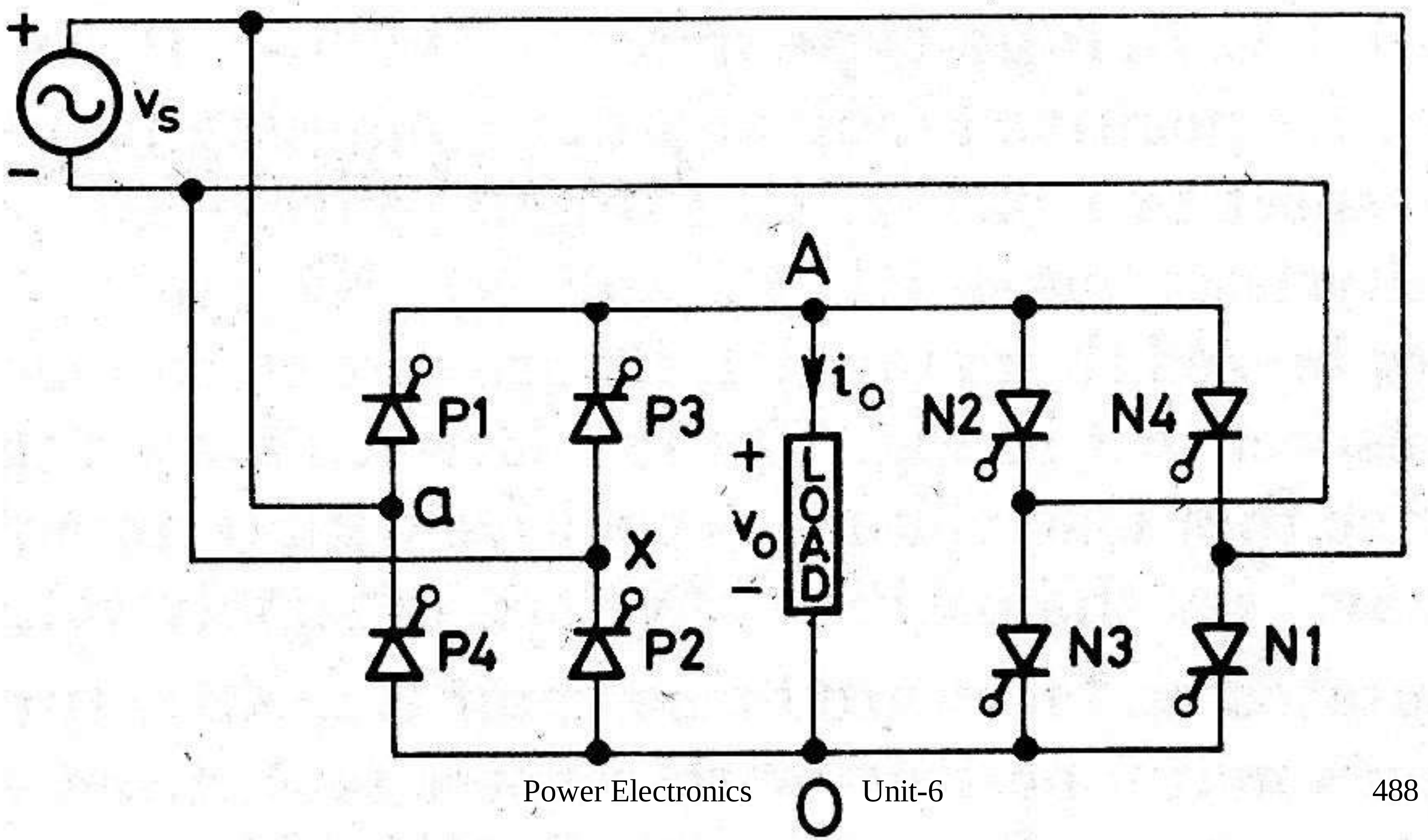
(ii) step-Down Cycloconverter (fo < fs)

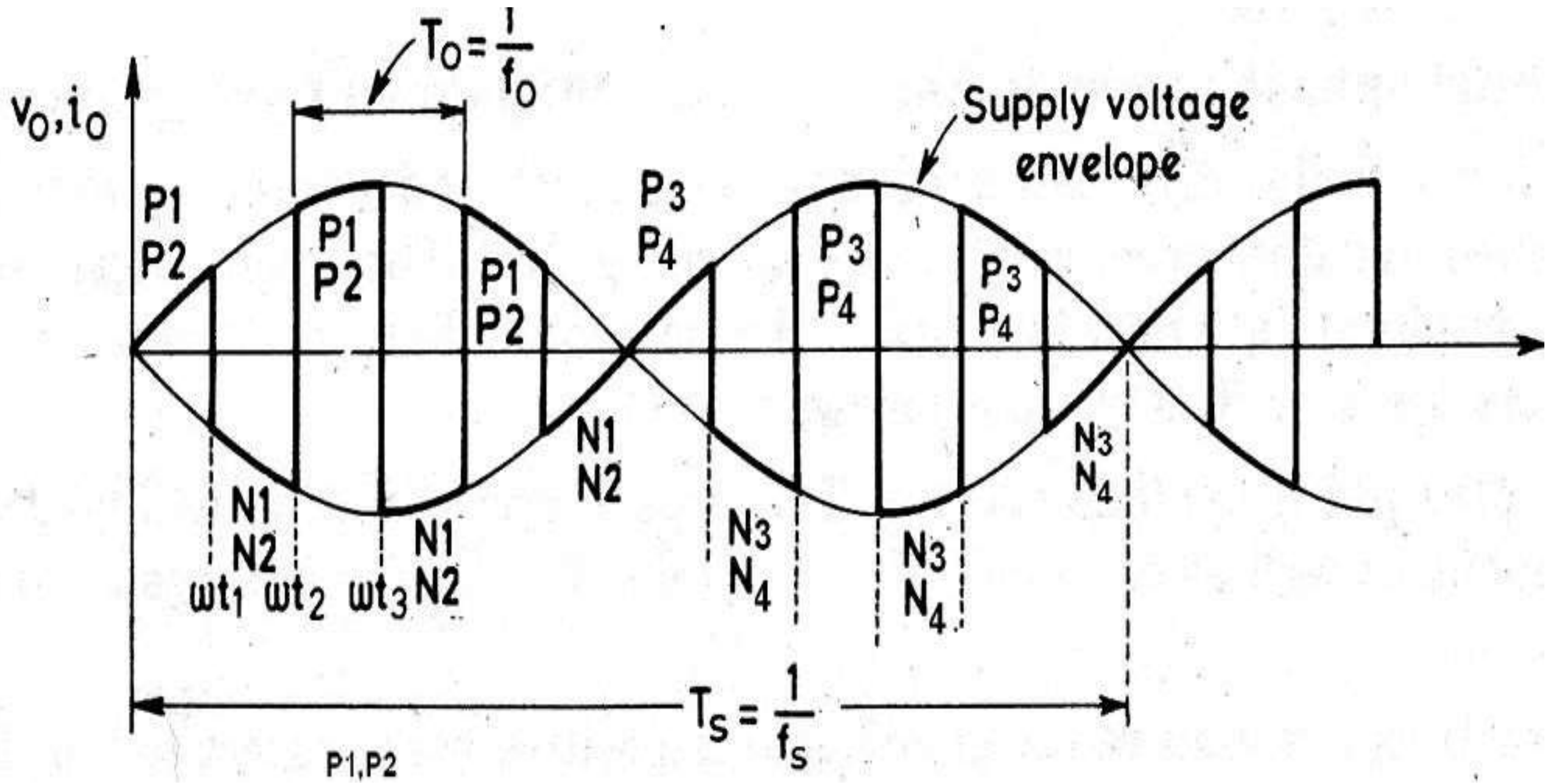
Single phase to single phase Mid point type step-up Cycloconverter with R load




$T_0 = \frac{1}{f_0}$
v_0, i_0
Supply voltage envelope
P2
P1
P1
P1
P2
N2
N2
N2
N1
ωt_1 ωt_2 ωt_3
$T_S = \frac{1}{f_S}$

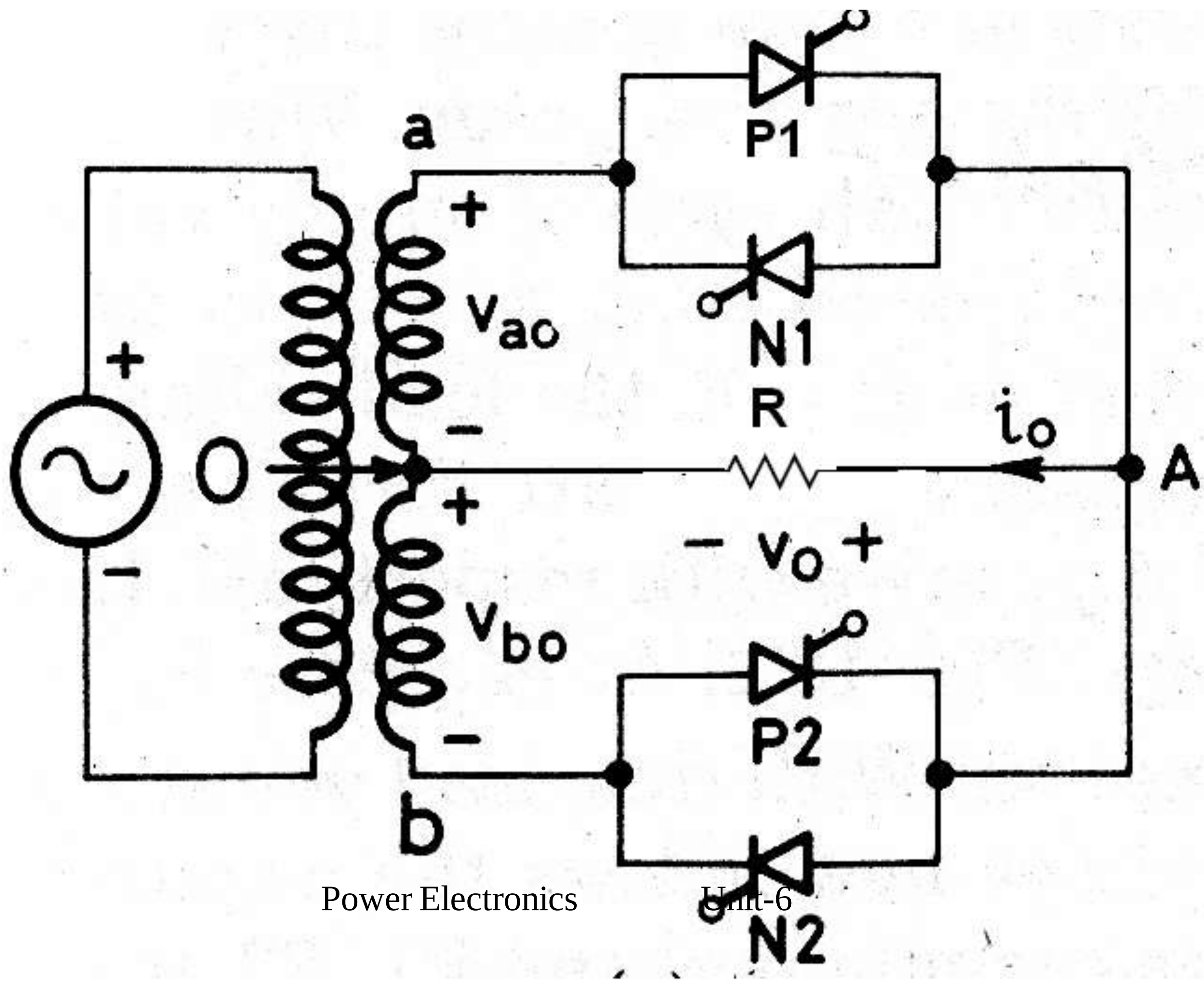
Single phase to single phase Bridge type step-up Cycloconverter with R load





$T_O = \frac{1}{f_O}$
v_O, i_O
Supply voltage envelope
P1 P2
P1 P2
P1 P2
P3 P4
P3 P4
P3 P4
N1 N2
N1 N2
N1 N2
N3 N4
N3 N4
N3 N4
ωt1 ωt2 ωt3
$T_S = \frac{1}{f_S}$
P1,P2

1-φ to 1-φ Mid point type step-Down Cycloconverter with R load



Output voltage (Vo) and current (Io) waveform

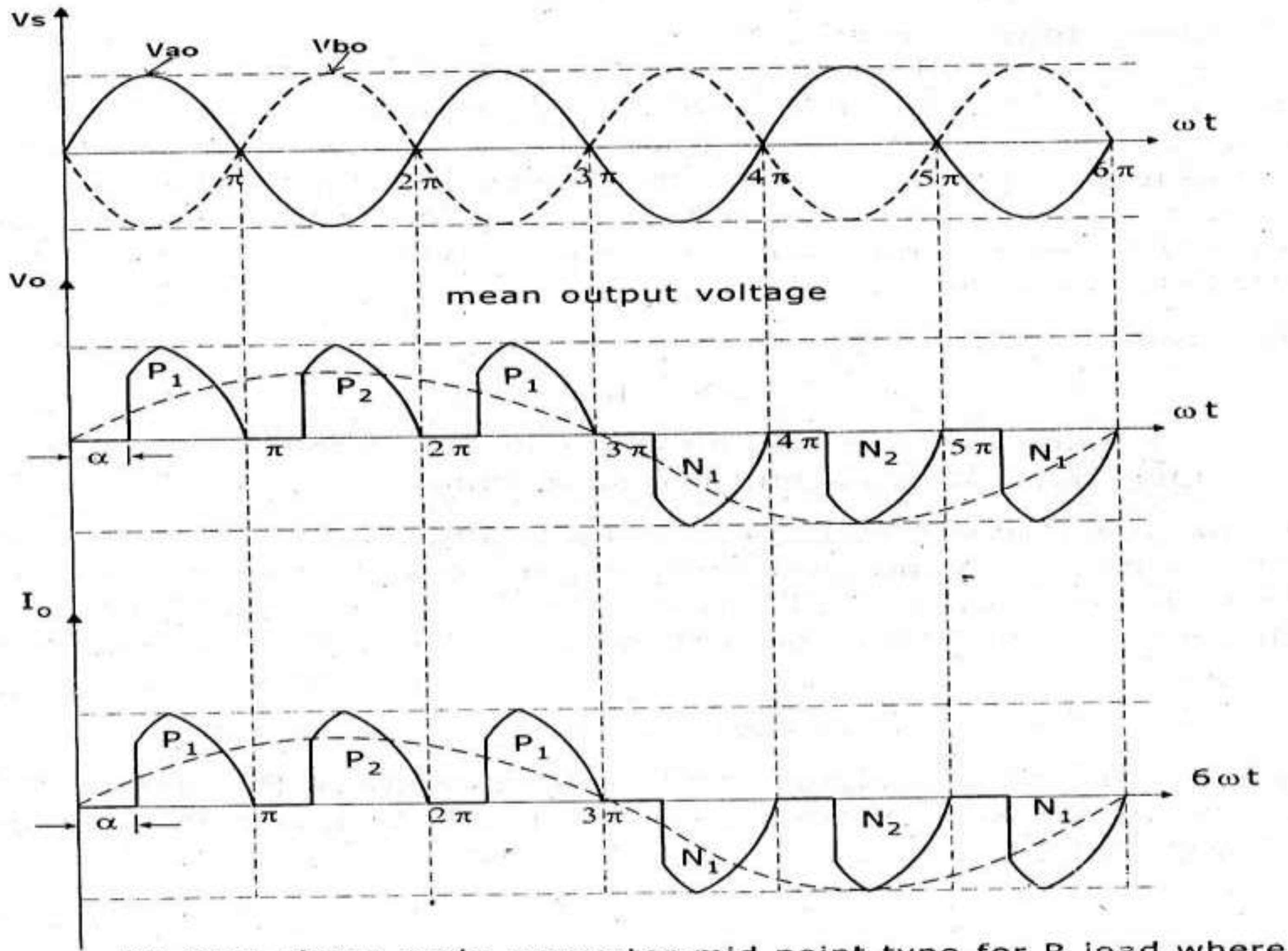
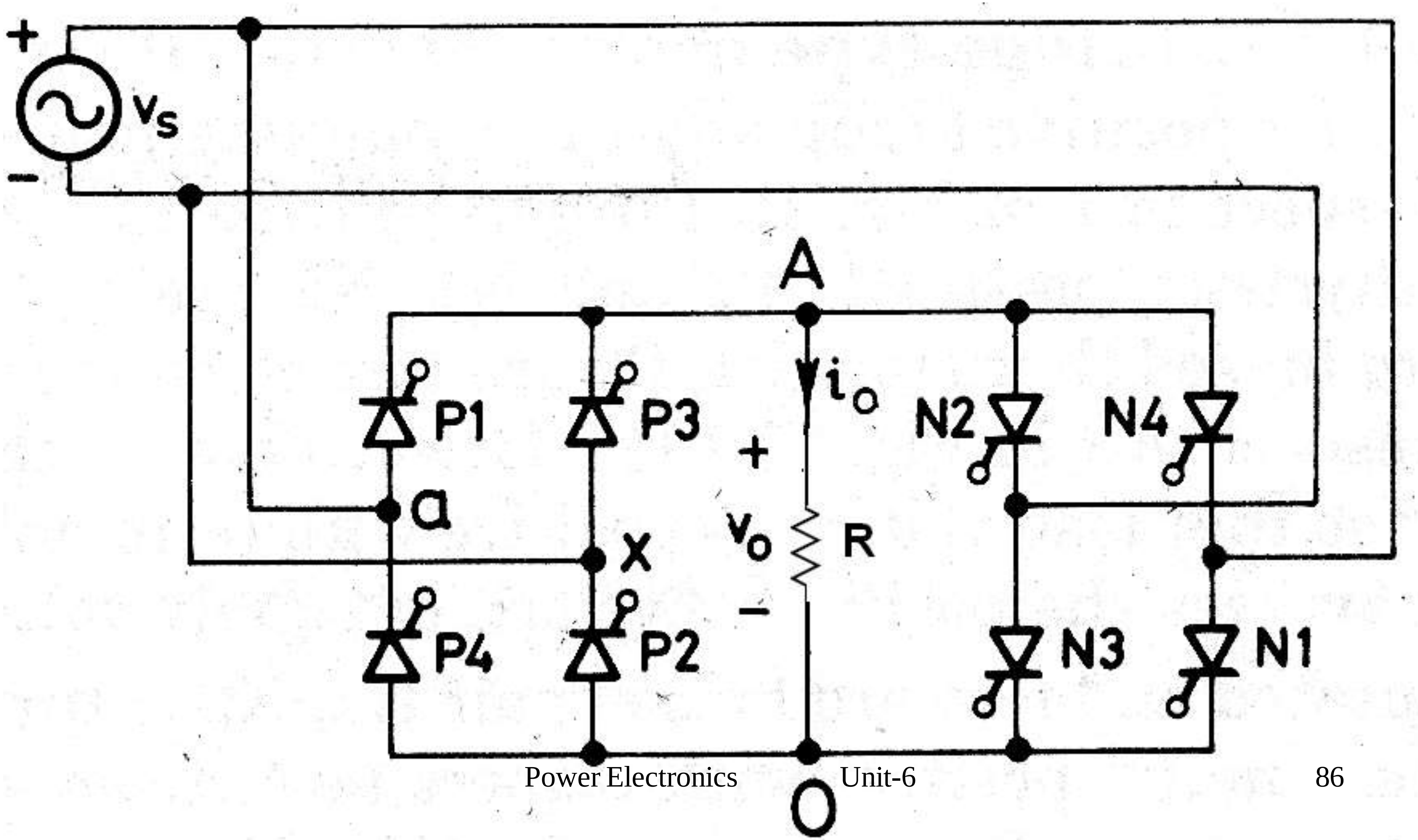


Fig. Step down cyclo converter-mid point type for R load where α is firing angle

1-φ to 1-φ Bridge type Cyclo-converter with R and R-L load

1-φ to 1-φ Bridge type step-Down Cycloconverter with R load



Output voltage (Vo) and current (Io) waveform

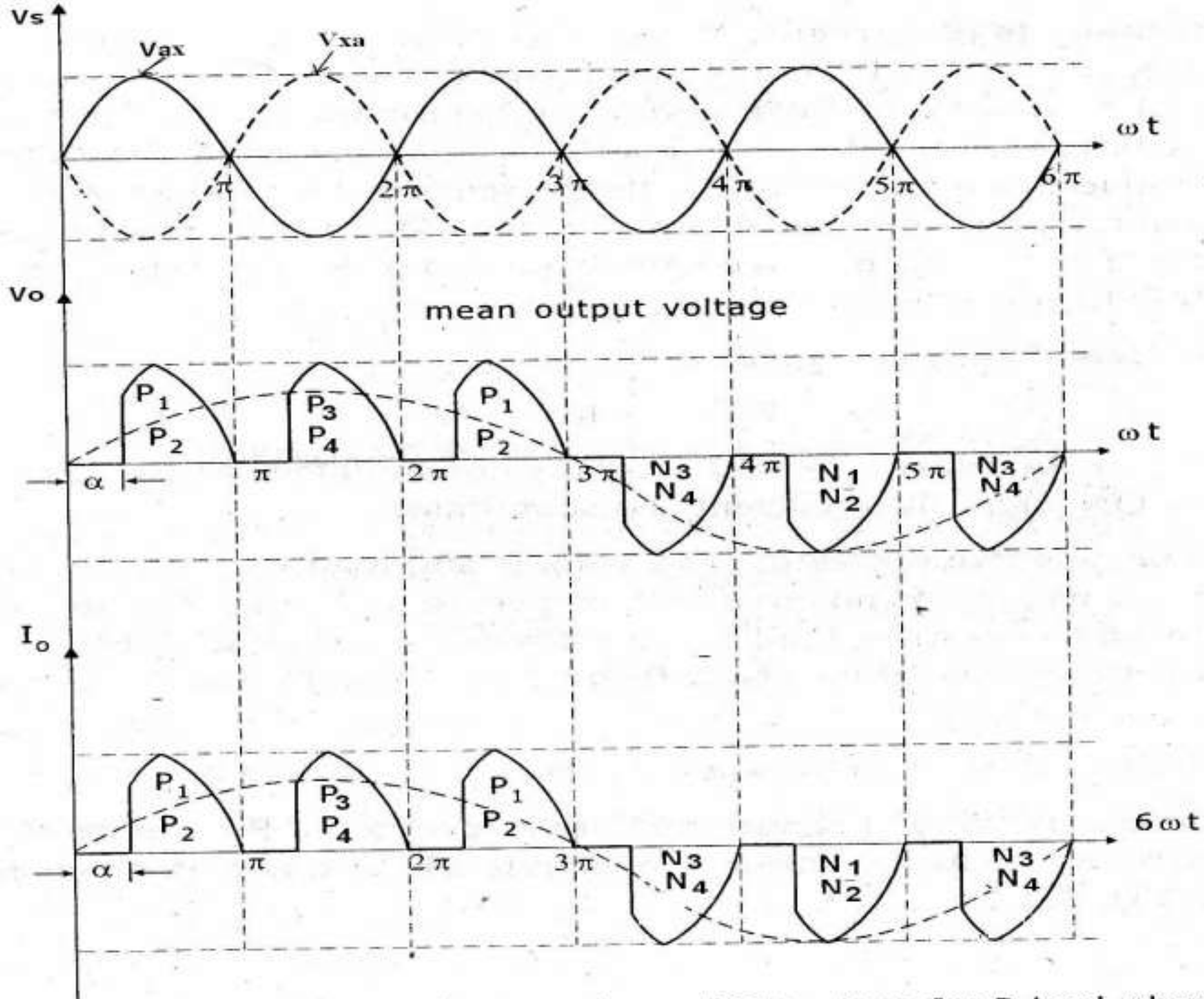
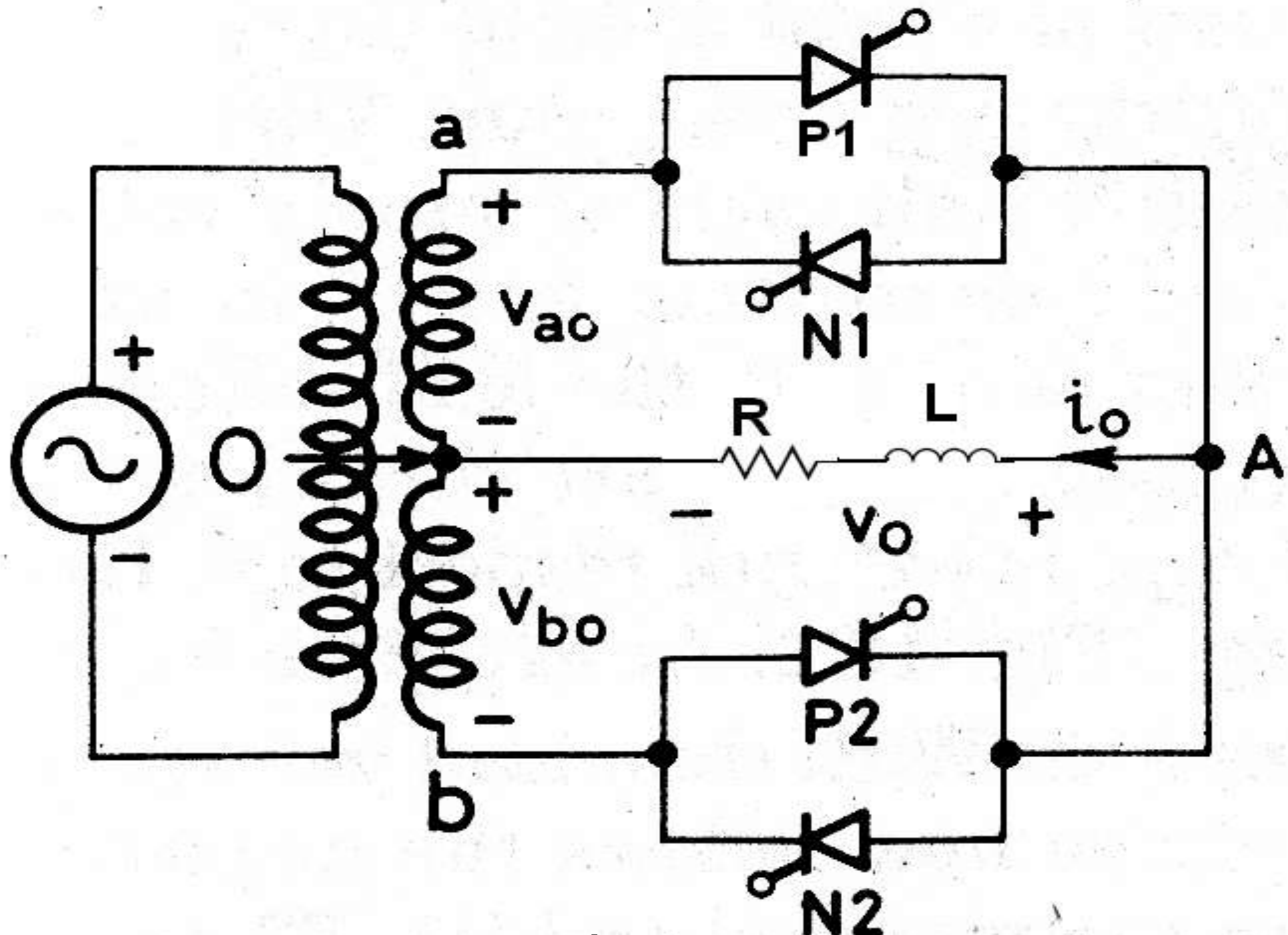
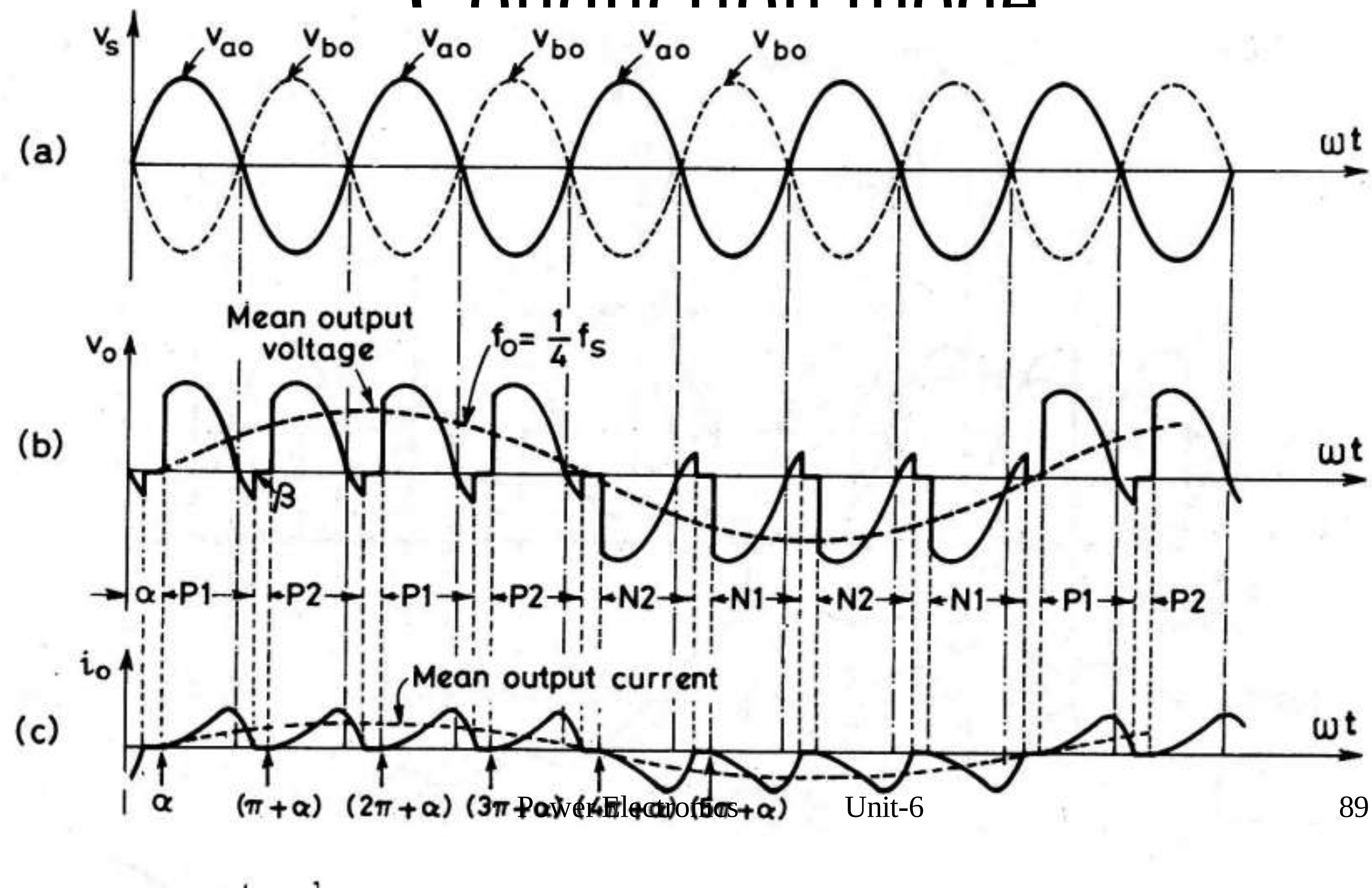


Fig. Step down cyclo converter- Bridge type for R load where α is firing angle

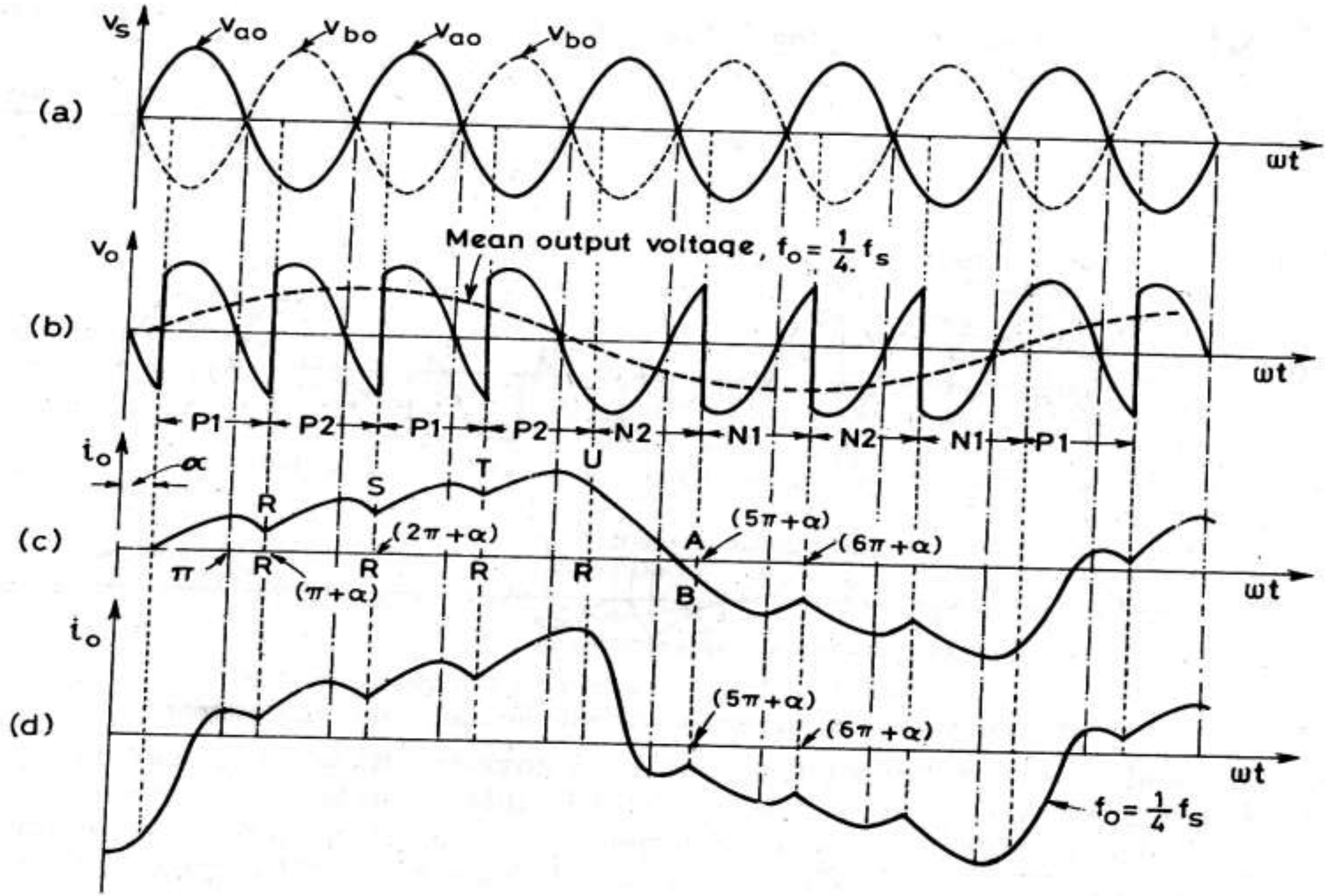
1-φ to 1-φ Midpoint type step-Down Cycloconverter with R-L load



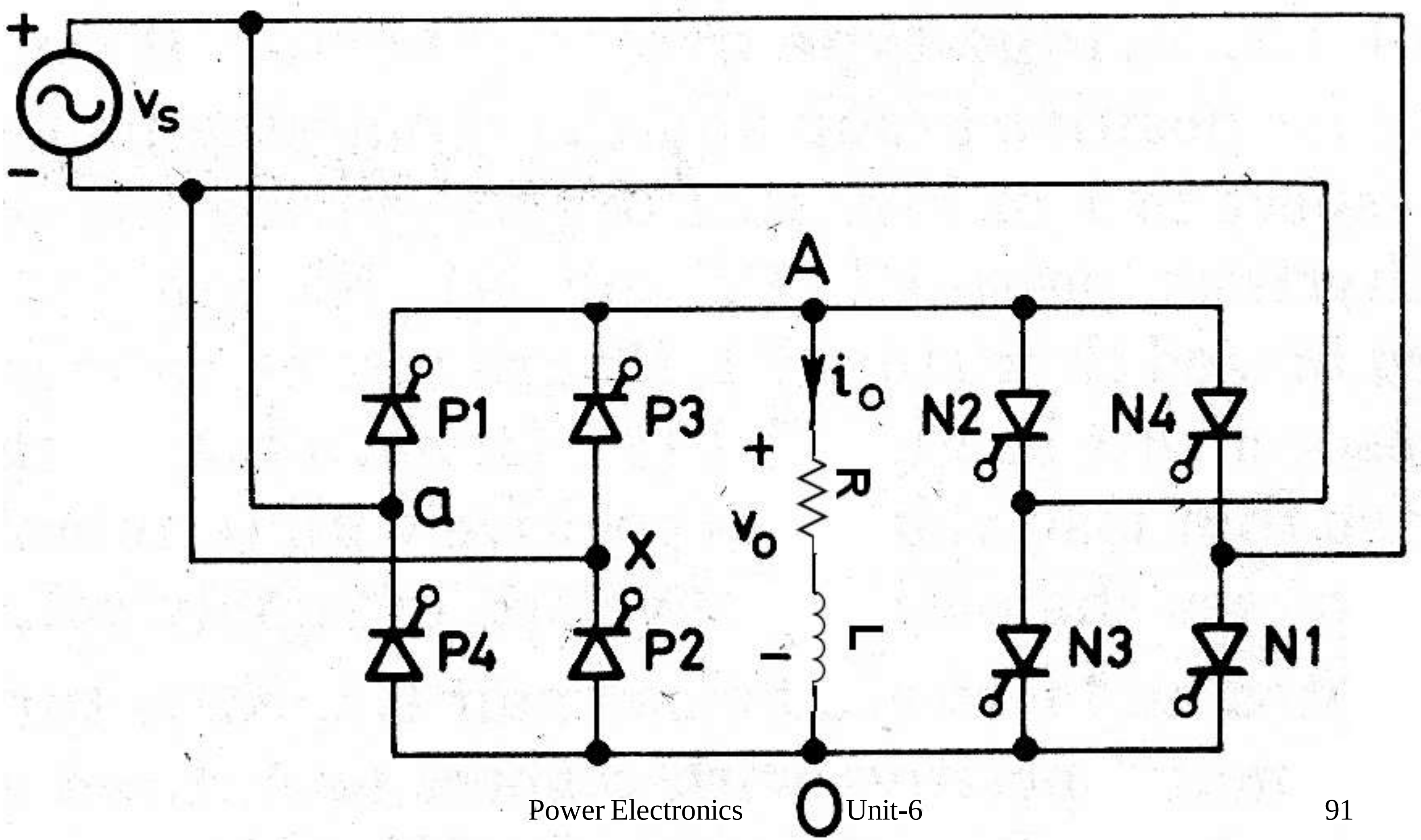
Output voltage (Vo) and current (Io) waveform for Discontinuous Conduction mode



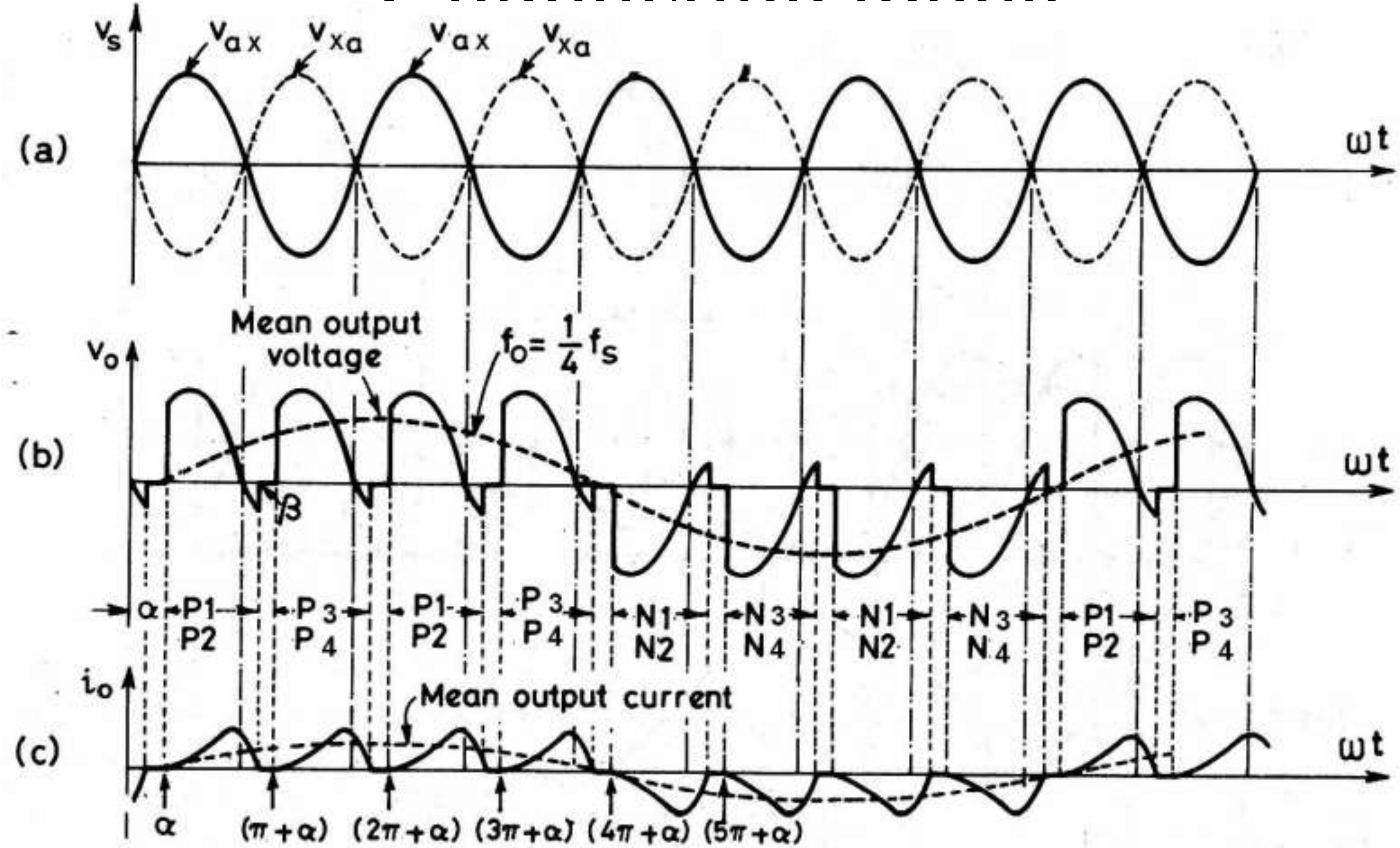
Output voltage (Vo) and current (Io) waveform for Continuous Conduction mode



1-φ to 1-φ Bridge-type step-Down Cycloconverter with R-L load



Output voltage (Vo) and current (Io) waveform for Discontinuous Conduction mode



Output voltage (Vo) and current (Io) waveform for Continuous Conduction mode